NATURAL RESOURCES

CLIMATE

The Pacific Ocean is a moderating influence on the climate of the parks. The parks have wet, mild winters and relatively dry summers with frequent coastal fog. Most rain falls between November and March, although it can rain any time. Annual rainfall averages 70 inches but can vary erratically between locations. Inland areas along the Smith River may have more than 100 inches of annual precipitation. Winter storms from the Pacific Ocean bring intense rainfall over several hours or days, particularly warmer storms from lower latitudes. These storms may cause both small streams and larger rivers to flood. Snow is infrequent and usually does not last long even at higher elevations inland.

Temperatures vary only slightly from summer to winter along the coast. Inland areas such as Jedediah Smith Redwoods State Park and the Redwood Creek basin have a greater fluctuation in temperatures. Mean temperatures at Prairie Creek Redwoods State Park are 47°F in January and 59°F in June. Temperatures above 90°F or below freezing are rare.

Winds come from the northwest or south-southwest and are generally light. Intense winter storms may be accompanied by damaging winds. Occasionally in the fall, a warm dry wind from the east produces a rapid drying effect, intensifying the fire hazard in the normally moist redwood forests.

Fog is a dominant climatic feature, generally occurring daily in the summer and not infrequently during the rest of the year. Fog occurs mostly within a few miles of the coast. Fog may extend inland as far as Hiouchi. The Bald Hills and the Little Bald Hills are generally free of fog because of their elevation and distance from the coast.

AIR QUALITY

Redwood National Park has been designated as a class I airshed pursuant to Part C of the Clean Air Act, as amended (42 USC 7401 et al.). State park lands within Redwood National and State Parks are classified as class II airsheds, with some areas being considered for reclassification to class I. Class I and class II designations are given to areas where air quality is cleaner than the national ambient air quality standards. Class I areas have the most stringent regulations for the protection of air quality, permitting the lowest increments of air quality degradation, whereas class II status allows moderate deterioration that might accompany well-planned growth.

The parks have been assigned to the North Coast Air Basin by the California Air Resources Board, which is under the jurisdiction of the North Coast Unified Air Quality Management District. A particle monitor in the parks measures fine particle mass (matter less than 2.5 micrometers in diameter), sulfates, nitrates, and aerosol elemental composition. An ozone and meteorological monitoring site operated in the parks between 1987 and 1995. Other monitoring stations are in Crescent City and Eureka.

Air quality in Redwood National and State Parks is considered good to excellent because of the low population, scarcity of pollutant sources, and prevailing westerly ocean winds. All federal standards are consistently achieved, including those for ozone, carbon monoxide, particulate matter, nitrogen dioxide, sulfur dioxide, and lead. The most significant air pollutant in the parks is PM_{10} (particulate matter less than 10 micrometers in diameter), which is primarily from broadcast and the industrial burning of timber harvest slash piles. In the past, total suspended particulates exceeded air quality standards, but improved technology, better use of materials, and fewer sawmills (and especially their tepee burners) in the region have resulted in a reduction in suspended particulates. Two industrial sites along Humboldt Bay (50 miles south of the park) are the most serious point sources of pollution. Local views and scenes are often impaired by fog, rain, low clouds, salt spray haze, and natural forest haze inversion.

SOILS AND GEOLOGY

Geology

Northern California is tectonically very active, and its complex geology and topography are controlled by movement along faults and crustal plates. The topography of the parks is influenced by several north-northwest trending faults. They range from low-angle thrusts to vertical faults and in most areas form the boundaries between major lithologic units in the parks. Two important faults cut through Prairie Creek Redwoods State Park — the Lost Man and Grogan Faults. The Grogan Fault, a well-defined north-northwest lineament that also bisects the Redwood Creek basin, has brought two distinctive rock types into contact with each other. Other faults that are perpendicular to the primary north-northwest fault orientation create the trellis-like drainage found in the parks (NPS 1997b *Erosion Control and Disturbed Lands Restoration Plan*, in-house draft environmental assessment). Late Cenozoic uplift and stream erosion are particularly evident in the steep inner gorges of Redwood Creek basin (NPS 1996).

Mesozoic-age (Jurassic to Cretaceous) rocks of the Franciscan complex underlie most areas of Redwood National and State Parks. The Franciscan complex is bounded on the west by the Cascadia subduction zone and on the east by the South Fork Mountain fault (or Coast Range thrust). The Franciscan complex was laid down on the ocean floor as deposits of sand and mud about 150 to 100 million years ago. These deposits were carried eastward on the oceanic plate, accreted to the North American continent, and eventually uplifted to form the Coast Range (for more information on plate tectonics see the discussion of earthquakes and tsunamis under the "Public Safety" section of the "Affected Environment"). Through time, folding and faulting further complicated the Franciscan complex rocks. Bedrock beneath the parks is mostly composed of sedimentary graywacke sandstone, mudstone, metamorphic schist, and minor amounts of conglomerates and melange. Other deposits include Tertiary marine deposits and serpentinites in the Little Bald Hills area just east of Crescent City. Pliocene/Pleistocene cobbles, sands, and silts of the Prairie Creek formation are thought to have been deposited in a river delta laid down by the Klamath River more than two million years ago. Quaternary alluvial and marine deposits blanket the stream valleys and coastal areas of the parks.

Soils

Soil development occurs in response to the weathering of the parent materials (rocks and alluvial deposits) and input from surface materials (vegetation), and varies depending on the topography (slope, aspect, and hydrologic features), underlying rock composition, and time. For the most part, the soils in the parks are well developed because the mild wet climate has caused a high degree of weathering of the underlying materials. Most of the soils have strongly developed surface horizons that are rich in organic matter and nutrients, particularly in areas that (1) have coniferous forests, oak woodlands, and prairies, (2) are moderately coarse textured, and (3) have infiltration capacities but possess little cohesion and very low shear strength. The steep terrain, rainy climate, and deep, medium-textured soils make the area very susceptible to erosion.

The soils in the parks have developed primarily from rocks of the Franciscan complex. Underlying geologic units strongly influence the nature of the soils, depending on their mineralogical and chemical composition and susceptibility to weathering and erosion. Residual soils are found in isolated areas on sloping ridge crests, and alluvial soils have formed in alluvial valleys, on floodplains, and on stream terraces.

Descriptions of the soils are derived from detailed soil/vegetation maps. Upland soils were mapped on a quad-by-quad basis in the Humboldt–Del Norte Counties, California, soil vegetation surveys (Alexander et. al 1952–78), and agricultural lands (valley bottoms) were delineated by staff at the University of California at Davis (McLaughlin et al 1965). The soils in Redwood Creek basin have been further classified by NPS staff, and these data are by far the most complete and detailed soils information in the parks.

Certain soil properties and other local conditions may restrict land uses. Shallow soils, fine or skeletal textures (more than 35% rock fragments that are larger than 2 millimeters), steep slopes erodible due to clays or weak underlying materials, and too little or too much drainage can make some areas inappropriate for certain land uses. These characteristics would be considered when planning development projects in the parks, and facilities would not be sited in any areas that contain highly erodible soils.

Erosion

Certain rivers in northwestern California, such as Redwood Creek and the Mad, Eel, and Mattole Rivers have naturally high sediment yields because of recent tectonic activity (uplift of the mountains), relatively weak geologic materials, steep slopes, and high precipitation rates. These conditions combined with land use activities such as timber harvesting, road construction, and ranching give the region one of the highest denudation rates in the United States (Jones and Stokes 1981). The rate of erosion for the north coast region ranges from 6.4 to 16 tons per acre per year, 10–100 times the rate for other river basins in the country (CDPR 1982 & 1983).

Many areas of the parks are susceptible to mass wasting — such as debris slides and avalanches, block falls, shallow and deep-seated landslides, streamside landslides, and earthflows. During periods of high precipitation, slope failures commonly occur in watersheds impacted by logging activities, in areas along Highway 101 near Del Norte Coast Redwoods State Park and the Prairie Creek bypass, and along steep terrain throughout the parks. The parks' policies are to allow natural erosion processes to continue, but where these processes have been accelerated by human activities such as logging, measures would be undertaken to limit damage to RNSP resources.

The coastline of the parks is subject to direct waves, high tides, storm waves and surges, tsunamis, sea cliff retreat, landslides, block falls, and surface erosion. Fluctuations in ocean levels and climate, tectonic activity, composition of the underlying bedrock, and land uses are factors that influence the rates and types of erosion along the coast. Landslides and slumping of the unstable Franciscan complex and other coastal deposits have caused road damage during the rainy season from November to March. In low-lying areas along the coast, such as Freshwater Lagoon, the natural coastal processes and near-shore marine ecosystems have been altered by the presence of Highway 101.

Redwood Creek Basin — Past Logging Activities and Watershed Restoration

In 1978, 48,000 acres were added to Redwood National Park

> to protect existing irreplaceable Redwood National Park resources from damaging up slope and upstream land uses, to provide a land base sufficient to insure preservation of significant examples of the coastal redwood in accordance with the original intent of Congress, and to establish a more meaningful Redwood National Park for the use and enjoyment of visitors. . . . The Secretary . . . is further authorized . . . to initiate . . . a program for the rehabilitation of areas within and upstream from the park contributing significant sedimentation because of past logging disturbances and road conditions, and, to the extent feasible, to reduce risk of damage to stream side areas adjacent to Redwood Creek and for other reasons.
>
> (Public Law 95-250, March 27, 1978)

Public Law 95-250 authorized Congress to appropriate up to $33 million to carry out the rehabilitation provisions of the act; to date, about $13 million has been appropriated for these restoration efforts. Before watershed restoration activities began, timber had been harvested from more than 62% of the watershed upstream of the confluence of Prairie Creek with Redwood Creek and the area was traversed by about 1,110 miles of logging and ranch roads and 5,400 miles of skid roads. The park expansion lands included about 415 miles of logging roads and more than 3,000 miles of skid roads (*Redwood Creek Watershed Analysis*, in press). (There were then about 2,400 miles of skid roads and about 695 miles of logging roads in the park protection zone.)

Public Law 95-250, the expansion legislation, also established a park protection zone covering 33,000 acres of private timberlands immediately upstream from the national park in the Redwood Creek watershed. In conjunction with California's timber harvest plan process, RNSP resource staff review proposed timber harvest activities in this zone and throughout the Redwood Creek basin. Other efforts to protect downstream park resources from upstream land use include reviewing newly proposed timber harvest regulations, monitoring sediment movement and implementing erosion prevention work, and road decommissioning on private lands in the Redwood Creek basin. In 1995 a framework for implementing cooperative erosion prevention work on private lands upstream from the parks was established through a memorandum of understanding among Redwood National and State Parks, other government agencies, and private landowners in the Redwood Creek basin. Although the national park is authorized to fund upper basin restoration work with NPS funds, most projects to date have been funded primarily by limited outside sources.

The greatest human-induced threat to downstream aquatic and riparian resources in and along the main channel of Redwood Creek are the roads upstream of the national park. Currently, there are about 1,110 miles of logging roads upstream from the park boundary in Redwood Creek basin, and nearly half of these roads have not been maintained. These roads were originally built to less than current standards, crossing steep slopes on unstable soils that are prone to landslide and fluvial erosion. The potential for stream diversions at stream crossings is common. Roughly 72% of the total sediment transported by Redwood Creek originates from areas upstream of the park (Madej 1991). Large-scale fluvial erosion resulting from diversions of streams at road crossings can account for 30% to more than 60% of the erosion occurring within a watershed (RNSP 1997b; USGS 1995; Hagans et al. 1987).

In 1978 a watershed rehabilitation program was initiated in Redwood National Park that concentrates on preventing human-induced erosion and encourages the return of natural vegetation patterns in the watersheds. The program has emphasized erosion prevention by restoring natural runoff patterns through removing road fill from stream and water flow courses. RNSP staff are currently using a watershed-by-watershed approach that will prioritize and restore the areas that pose the greatest erosional threats first. When the watershed restoration program began in Redwood Creek basin, there were 415 miles of logging and ranching roads within the legislated national park boundary. To date, about 190 miles of these roads have been treated to reduce road-related erosion and assist in overall ecosystem recovery, and now there are 225 miles of roads remaining. About 155 miles of the remaining logging roads within the park in the lower basin (with 683 stream crossings and 375 culverts) are scheduled for treatment to reduce erosion potential. Seventy miles of logging roads are not scheduled for removal at this time because they are necessary for public and administrative access. Ultimately, the Redwood Creek ecosystem within the national park should be restored to conditions similar to what would have existed without human disturbances.

The first *Watershed Rehabilitation Plan* was written by NPS staff in 1981. Over the years, careful monitoring of the results and costs has improved the success of the restoration treatments, and the plan is currently being updated to reflect these cost savings and improved technology. In addition, the updated plan incorporates a reranking of the priorities of work based on current road conditions and existing threats to sensitive natural resources.

Study results clearly indicate that in areas subjected to intensive timber harvest, road networks are the primary cause of accelerated mass wasting and fluvial erosion, and that surface erosion is a minor component of the total sediment yield. Nearly half (45%) of the total sediment in Redwood Creek is caused by mass movements, but because some of the mass movements occur naturally, it is difficult to determine how much is attributable solely to timber harvesting. Erosion directly linked to logging and road-building activities (such as surface erosion on road surfaces, collapsed stream crossings on abandoned roads, and gullying caused by diversions of overland flows), contribute 42% of the total sediment load in Redwood Creek basin streams. Bank erosion makes up the remaining 13% of the sediment load (Spreiter, Franke, and Steensen 1995).

Logging roads cut into the hillslopes alter the natural hydrology, concentrate water on the surface, accelerate erosion, and in many cases result in slope failure. During intense storms and as roads age, their potential for catastrophic failure increases due to the plugging and rusting of culverts, the decay of buried organic debris, and the plugging and diversion of groundwater and streamflow. These failures add tremendous quantities of sediment to the streams in the watershed and have cumulative downstream impacts that affect terrestrial, riparian, and aquatic communities. Materials eroded from hillsides can overwhelm the transport capacities of the streams, causing aggradation (accumulation of sediment in and along the streams), channel widening, and the loss of streamside vegetation. The influx of sediment has also deteriorated water quality (raised water temperatures, lowered dissolved oxygen, and increased turbidity) and decreased the quality and quantity of fish spawning habitat in Redwood Creek and its tributaries.

Some road segments, although revegetated and displaying no signs of instability, still pose a serious erosion threat if they fail and contribute sediment to stream channels. Above average rainfall during fall 1996 and large storms in December 1996 and January 1997 saturated soils along the coast of northern California. Roads within and upstream of the parks, particularly in the Redwood Creek basin, sustained severe damage. Much of this damage occurred from large landslides initiated by saturated fills along abandoned logging roads. Redwood National and State Parks have received supplemental appropriations to treat the extensive damage caused by these storms inside the parks. These treatments vary from road repairs to watershed restoration.

Other Watershed Disturbances

Timber harvesting in the watersheds upstream of the parks has the potential to adversely affect numerous RNSP values. Besides the increased potential for erosion through road building and the use of heavy equipment during harvests, harvesting within riparian areas removes the vegetative cover that maintains optimum stream temperatures and greatly reduces the supply of large woody debris necessary for fish habitat and regulating sediment movement throughout the aquatic system. Also, clear cuts directly adjacent to forested land in the parks create microclimatic changes that can penetrate more than 300 feet into the adjacent parklands.

Specific areas of concern in the state parks include the entire basin of Mill Creek upstream of Jedediah Smith Redwoods State Park, the upper West Branch of Mill Creek in Del Norte Coast Redwoods State Park, and those portions of the Prairie Creek watershed containing the headwaters of the east side tributaries in Prairie Creek Redwoods State Park.

In areas where harvests are proposed that may affect RNSP resources, the state parks are authorized under the California *Forest Practice Rules* to become a member of the state's interdisciplinary review team. Team members ensure that harvest plans conform to the rules and the state's environmental laws. Also, timber harvest plans must designate any harvest areas within 200 feet of RNSP lands as a special treatment area. Within these areas silvicultural methods must be proposed that are compatible with the purposes of the parks.

The legislation that added 48,000 acres to the national park also established a park protection zone covering 33,000 acres on private timber lands in the upstream portion of the Redwood Creek basin. There are about 1,110 miles of logging roads in this area, and inventories show that nearly half of these roads present a significant source of sediment to downstream areas of Redwood Creek. NPS staff work with private interests in this zone to limit the effects of logging and other land use practices. Besides reviewing timber harvest plans and regulations,

PAST ROAD RESTORATION PROJECT SITES

BEFORE
C- Road, E erald Creek
1982 beginning excavation
of steep inner gorge road fill.

DURIN
C- Road, E erald Creek
inter 1982
after excavation of steep
inner gorge with mulch,
and revegetation to
prevent erosion.

AFTER
C- Road, E erald Creek
1988 restored inner gorge
with vegetation regrowth.

PAST ROAD RESTORATION PROJECTS

BEFORE
Ah Pah Road
Before restoration road crosses hillside.

AFTER
Ah Pah Road
One year after restoration, hillside reshaped similar to preroad configuration with reestablished native vegetation.

BRFORE
W-Line, Dolason Creek
1980 before restoration road crosses hillside.

AFTER
W-Line, Dolason Creek
1982 Two years after restoration, hillside reshaped similar to preroad configuration and native vegetetion reestablished. Road was partially converted to backcountry trail.

staff monitor sediment movement, and occasionally remove or repair roads in conjunction with cooperating landowners.

Construction of logging roads or reconstruction of existing roads will continue to occur upstream of the national park in the park protection zone. Maintenance of these roads is governed by the California *Forest Practice Rules* and is required for three years after their construction. If the road is designated as a temporary road, stream crossings must be removed, while a permanent designation requires that stream crossings must pass a 50-year return interval storm. Culverts on permanent roads that are not maintained after the required three-year period would, over time, become plugged, develop holes, fail, and cause damage to downstream resources.

RNSP staff also monitors continuing road failures along the Highway 101 Bypass around Prairie Creek Redwoods State Park and reviews repair work undertaken by the California Department of Transportation. Construction of the bypass resulted in a large influx of fine-grained sediments into pristine streams in the state park during an October 1989 storm.

Sediment catchment basins have been constructed along the Highway 101 bypass to collect sediment and runoff from slopes cut into the hillside. Containment tanks were placed adjacent to emergency truck escape ramps to collect runoff or spilled materials, such as petroleum products or materials being hauled, and to prevent contamination of downstream RNSP resources. Caltrans (the California Department of Transportation) maintains the basins and tanks under conditions established by the National Park Service, the California Regional Water Quality Board, and the California Department of Fish and Game to protect downstream aquatic resources and sites.

WATER RESOURCES

Surface Water

Surface water resources in Redwood National and State Parks consist of saltwater (Pacific Ocean), freshwater (streams and rivers), and transitional areas (estuaries and lagoons).

There are about 35 miles of shoreline within the parks. The western boundary of the national park extends 0.25 mile beyond the mean high tide line. These offshore lands are held in title by the State Lands Commission with the exception of lands in the northern end of the parks that are held by the Crescent City Harbor District. NPS jurisdiction applies to the area 0.25 mile offshore within the legislated boundary of the park. The coastal jurisdiction of state park lands extends to 1,000 feet west of the ordinary high-water mark.

Three large river systems drain most of the parklands in many areas and have cut deep gorges through forested mountainous terrain. Redwood Creek has a total drainage area of 278 square miles and drains into the southern portion of the national park; one-third of this area is within Redwood National Park. Redwood Creek flows northwestward, follows the Grogan Fault for most of its length, and has many steep, short tributaries that drain relatively small areas of the watershed. Incised inner valleys in Redwood Creek basin are highly susceptible to mass wasting by shallow debris slides and debris avalanches, especially in areas traversed by abandoned logging roads (for more information see the "Past Logging Activities and Watershed Restoration" section). Natural surface runoff patterns are altered by roads, which causes accelerated natural surface erosion and mass wasting.

The Klamath River, the largest river in the north coast area (drainage area of 15,000 square miles in California and Oregon) flows through a narrow strip of parkland in the central portion of the parks. The Smith River flows through the northern part of the parks (Jedediah Smith Redwoods State Park) and drains 632 square miles of Oregon and California that are very steep and prone to landslides. Many other small tributary streams are also included within the parks' boundaries.

Annual stream flows in the parks are highly variable due to seasonal precipitation in the region. The rainy season typically extends from October through April, but most of the precipitation and subsequent high flows occur between November and March, with less precipitation and corresponding low flows during the summer and fall. The Smith and Klamath Rivers drain large mountainous areas and are influenced by snowmelt. Snowmelt has only a minor impact upon the total runoff entering Redwood Creek. However, a few large floods, including that of December 1964 that caused the highest recorded peak flow on Redwood Creek, have been augmented by rapid snowmelt induced by warm rain (USGS 1975). Average annual discharge, peak, minimum, and average recorded flows for the major streams are presented in table 11.

There are no natural ponds or lakes within the parks, although lagoons, sloughs, and marshes occur as a result of oceanic and tectonic processes. The western half of the waters and shoreline of Freshwater Lagoon, southwest of Orick, are in Redwood National and State Parks; this is the only large lagoon in the parks. Espa Lagoon is a small, natural wetland at Gold Bluffs Beach. Two sloughs in the lower Redwood Creek valley are considered part of Redwood Creek estuary. There are several ponds adjacent to former mill sites in the parks — one on Richardson Creek (Marshall Pond) and one on Lagoon Creek. Several stock and fire suppression ponds and sediment catchment basins along the Highway 101 bypass are also considered artificial impoundments.

Groundwater

Groundwater aquifers are few in number and small in supply in the parks because most of the area is mountainous and is underlain by bedrock — conditions that do not provide for groundwater storage. Four groundwater basins, primarily near the mouths of the major rivers, have been identified by the California Department of Water Resources — including the Smith River plain, the lower Klamath River valley, the Prairie Creek area, and the Redwood Creek valley. The best aquifers occur in alluvium, terrace sediments, and dune areas of the parks. Additional small unnamed aquifers, such as the aquifer that supplies water to the Jedediah Smith area, are located throughout the parks, and water supplies are dependent on the complex subsurface geology (Frank Saylor, California Department of Health Services, pers. comm. 3/3/97).

Floodplains and Flooding

Streams in the parks are typically small and steep and do not have well-developed floodplains. However, there are floodplains near the mouths of the larger rivers and in areas that are less steep (Klamath and Smith Rivers and Redwood, Mill, and Prairie Creeks). Along Redwood Creek the floodplain is best developed in the flatter downstream portion of the river,

TABLE 11: FLOW STATISTICS AND BASIN AREAS FOR THE MAJOR STREAMS IN THE PARKS

STREAM	AVERAGE ANNUAL DISCHARGE acre-feet/year	AVERAGE FLOW cubic feet/second	PEAK FLOW cubic feet/second	MINIMUM FLOW cubic feet/second	BASIN DRAINAGE AREA square miles
Smith River at Crescent City[a]	2,721,000	3,772	228,000 Dec. 22, 1964	160 Oct. 24, 1964	609
Klamath River at Klamath Glen[b]	12,600,000	17,461	557,000 Dec. 23, 1964	1,310 Sept. 4, 1977	15,000
Redwood Creek at Orick[c]	734,700	1,019	50,500 Dec 22, 1964	2.1 Oct. 20, 1987	278

Source: NPS 1985, USGS 1997

a. Smith River period of record is 1932–96, gaging station 11532500.
b. Klamath River period of record is 1963–94 , gaging station 11530500.
c. Redwood Creek data period of record is 1954–96 , gaging station 11482500.

from McArthur Creek north to the national park boundary. Towards the south, in the upstream sections of the river, floodplains are discontinuous because of the steep valley sideslopes. Levees upstream from the Redwood Information Center in the lower portion of Redwood Creek were constructed to protect for approximately a 100-year flood event and to define the limits of the 100-year floodplain in those areas. The floodplain along Prairie Creek, a tributary of Redwood Creek, is relatively extensive and has commercial development, ranching activities, visitor facilities (including the Elk Prairie visitor center and campground), and the Davison Ranch structures.

Although not delineated, the campground at Mill Creek is probably within the 100-year floodplain. A small part of the Klamath River 100-year floodplain is within the parks' boundaries near the mouth of the river. No RNSP facilities are within the Klamath River floodplain. The Smith River flows through Jedediah Smith Redwoods State Park, and portions of the state park campground are in the 100-year floodplain.

The 100-year floodplains have been approximated for some areas of the parks' rivers (Zone A maps) by the Federal Emergency Management Agency (1982, 1983, 1986). Mapping of the 100-year floodplain in the parks has been done for the Smith River near Hiouchi and for Prairie Creek from the fish hatchery south to Orick. More detailed floodplain maps based on hydrologic studies and cross sections of the rivers are typically done in populated areas that have significant flooding risk and have not been done for Redwood National and State Parks.

Land use activities have increased runoff and sediment transport by the removal of vegetation for timber harvesting, agriculture, grazing, and mining. These activities have resulted in additional sediment being deposited in stream channels, reduced capacity and gradient, obstructed flows, and increased channel bed elevation.

The rivers and streams throughout the parks are subject to flooding, primarily due to the heavy amounts and seasonal concentration of precipitation (between November and March). Flooding near the mouths of the rivers is also commonly caused by high tides in conjunction with heavy rains and is often augmented by high winds. In Jedediah Smith Redwoods State Park, a 10-year frequency flood would overtop the banks of the Smith River in some areas. The Klamath River floods and overtops its banks about every four years and, because of its size and broad floodplain in its lower reach, poses a serious hazard to public health and safety. The upper portions of Redwood Creek flood at about the same frequency as the Klamath River. Flooding along the lower portions of Redwood Creek has decreased since construction of the federal flood control levees in 1968 because the water is now constrained by the levees. The flooding of January 1997 was estimated to be a five-year frequency flood on the Smith River, a 60-year frequency flood on the Klamath River, and an 11-year frequency flood on Redwood Creek (USGS 1997).

The highest recorded flood this century occurred during December 1964 when all of the river basins in the parks flooded. Peak flows of 50,500 cubic feet per second on Redwood Creek inundated Orick with 5 feet of water. High-water marks from this flood are still evident on trees throughout the parks. Extensive flooding also occurred in 1953, 1972, and 1975 (NPS 1985). Table 12 shows the flood frequencies and instantaneous discharges for the major streams in the parks.

Following the 1964 flood, local residents requested that the U.S. Army Corps of Engineers construct flood control devices that had been previously planned for lower Redwood Creek. In 1968 flood control levees were constructed on the lower 3.4 miles of Redwood Creek from the confluence with Prairie Creek downstream to within 1,000 feet of the Pacific Ocean (U.S. Army Corps of Engineers 1994). The levees offer protection against a greater than 200-year-flood. The last 500 feet of the levees are within the national park boundary and are the only flood control structures within the parks.

Federal and state wild and scenic river designations for the Klamath and Smith Rivers preclude

TABLE 12: RECURRENCE INTERVALS AND INSTANTANEOUS STREAM DISCHARGE FOR MAJOR STREAMS IN THE PARKS (CUBIC FEET PER SECOND)

Recurrence Interval	Smith River Discharge[a]	Klamath River Discharge[b]	Redwood Creek Discharge[c]
2-year	76,300	135,000	20,800
5-year	110,300	231,800	33,400
10-year	133,500	304,000	41,800
25-year	163,700	402,600	52,300
50-year	186,700	480,600	59,800
100-year	210,000	561,800	67,100
200-year	233,900	646,500	74,300
500-year	266,500	764,000	83,400

SOURCE: Flood frequencies run by Rick Hunrichs, USGS, Sacramento, CA, March 1997. Discharge numbers have been rounded to the nearest hundred.

a. Smith River, gaging station 11532500.
b. Klamath River, gaging station 11530500.
c. Redwood Creek, gaging station 1482500.

the construction of any water impoundment or flood control structures on these rivers. The mechanisms used to reduce flood damage on lands adjacent to the parks' rivers have been to control land uses and to use the regional flood warning system.

Estuaries

Within the parks' boundaries, there are estuaries at the mouths of the Klamath River and Redwood Creek. These estuaries (1) alternate between a fresh and brackish system and provide a transition and nursery area and migration route for anadromous fish, (2) are valuable habitats for a variety of fresh and saltwater species, (3) support recreational uses, and (4) supply water for farming and ranching activities in the valleys. Refer to the "Wetlands," "Floodplains," and "Water Quality" sections of the document for further discussion of the estuaries.

The Klamath River Estuary

Only a small portion of this estuary, at the mouth of the Klamath River, is under RNSP jurisdiction. The mouth of the Klamath River is dynamic and migrates across its floodplain. This estuary is accessible from local trails and beaches and provides RNSP visitors with a variety of recreational opportunities, including Yurok cultural activities at the Brush Dance site. The Yurok Tribe engages in a commercial fishery in the Klamath River estuary and subsistence hunting of eels at the mouth of the river.

The Redwood Creek Estuary

Redwood Creek estuary is about 2 miles west of the town of Orick (see Redwood Creek Estuary map). The boundaries of the estuary are U.S. Highway 101 on the south and Hufford Road and a levee access road on the north. The downstream portion of the estuary is within the national park's boundaries, while the upstream portions are owned by the county, and land surrounding portions of the estuary (the sloughs) are in private ownership. The Redwood Creek estuary includes the embayment and the north and south sloughs of Redwood Creek. The mouth of the river is dynamic, and its location is affected by changes in discharge, bedload, size and direction of waves, and the tidal cycle.

dwood Creek usually migrates between an unnamed point of land and several seastacks on the north, and the NPS Redwood Information Center on the south, although the river channel occasionally migrates further to the north and south. Before construction of the federal flood control levees along lower Redwood Creek, the embayment at the mouth of Redwood Creek was a broad, relatively deep pool landward of the beach in the summer and fall. Water levels in the estuary fluctuate throughout the year, with changes in discharge, tides, sediment deposition, and the shape of the river outlet.

Following high winter flows, stream discharge begins to decrease, and during the summer low flows, a berm is built up seaward of the embayment at the mouth of Redwood Creek. This is a natural occurrence and is related to stream flows and ocean conditions (swells, size and direction of waves, and tides). Offshore processes begin to cause the outflow channel to shift to the south, and an embayment forms behind the berm as the outflow channel rises. Throughout the late spring and early summer, offshore processes cause the channel to shift to the south with a progressive increase in water elevation and volume in the embayment. When in-stream flows are greater than outflow, seepage, and evaporation, water levels in the estuary rise. During this time, the outflow channel may completely close and begin to flood private properties and roads in the lower Redwood Creek valley. About 95 acres of nonpark lands may be subjected to flooding when Redwood Creek closes in the summer and fall (David Anderson, RNSP fisheries biologist, pers. comm. 7/97).

Water levels in the estuary have been controlled during the summer to alleviate high water caused by the closing of the embayment. In the past, uncontrolled breaching of the sand berm has been done to protect private property from flooding; this has been done by digging a trench through the narrowest part of the sand berm and draining water from the embayment. From 1982 through 1993, the National Park Service undertook a program of controlled breaching to protect adjacent lands from flooding while also retaining sufficient water to provide salmonid habitat. In 1992 a north slough channel was excavated to alleviate winter flooding in the estuary. Flooding of properties adjacent to the north and south sloughs may still occur in the summer and fall if the sand berm builds up and closes Redwood Creek.

Since the mid–1990s, the NPS policy has been to protect salmonid habitat from the adverse effects of an uncontrolled breach. The U.S. Army Corps of Engineers approved a section 404 permit for controlled breaching of the estuary during the summer and fall low-flow periods to protect fish habitat. Controlled breaching by RNSP staff could also prevent the occurrence of an uncontrolled natural breach that could have major adverse impacts on salmonid habitat. As a condition of the section 404 permit, the Corps stated that a longer term alternative should be pursued to manage water levels in the estuary. These measures may include the setback of levees, conservation easements, the raising of the county road above flood elevation, or outright land purchase in the lower Redwood Creek valley to protect the fisheries resource.

Redwood National Park was also issued another section 404 permit to allow emergency channel manipulation to protect the Redwood Information Center from damage that could occur from the southward migration of Redwood Creek.

Federal flood control structures along the lower 3.4 miles of Redwood Creek constructed in 1968 have impaired the physical and biological functions in the estuary and have resulted in the loss of fish habitat, the reduction in biological productivity of the estuary, and degraded water quality (decreased dissolved oxygen and increased temperatures in the north and south sloughs). The levees have also changed the circulation and sedimentation patterns in the estuary and allowed sediment of marine origin to be deposited during winter storms (Ricks 1983). After the levees were constructed, the river bypassed the last meander in Redwood

Creek and reduced circulation in the north and south sloughs, and about 50% of the lower estuary became filled with sediment and isolated from the embayment. Because of sediment infill in the north slough channel, lack of circulation and resulting poor water quality, it can no longer support juvenile salmonids.

During construction of the Highway 101 bypass around Prairie Creek Redwoods State Park from 1987–92, about 214,000 cubic yards of gravel were mined from between the levees of lower Redwood Creek. Mining removed point bars and pools, widened the baseflow channel, spread the flow out, and reduced water depths at lower flows. As recently as 1992, only 25% of the amount of gravel removed had been redeposited in the lower river.

Construction of the bypass has caused substantial increases in sediment in Prairie Creek and its tributaries (NPS 1996). A gated culvert was installed through the south levee in 1988 to mitigate for fisheries losses caused by the highway construction; the culvert was built to help improve water circulation, water quality, and summer rearing habitat for juvenile salmonids in the south slough. The project does not alleviate sediment buildup in the south slough outlet, which still impedes fish access and water circulation and degrades water quality (NPS 1997b).

Using historical accounts and photographs of the estuary taken since 1948, staff have estimated that estuarine habitat for fish has been reduced by as much as 75% of its original extent.

Water Quality

The primary responsibility for water quality protection and enhancement in California has been delegated to the California Water Resource Control Board. In northern California, the North Coast Regional Water Quality Control Board is responsible for adopting and implementing the *Water Quality Control Plan* for the North Coast Region. The plan specifies objectives, requirements, and implementation plans to protect the beneficial uses of water in the north coast area, including the parks. Water quality objectives in the plan do not allow any degradation of surface or groundwaters or permit any alteration of natural conditions. The plan also specifies the maximum contaminant levels for point (discharge from a discrete point) and nonpoint (dispersed runoff) sources. For more information on water quality regulations and policies, see the topic of water quality in the "Regulations, Methods, and Assumptions" section of this document.

Water quality is determined by measuring various physical, chemical, and biological parameters, such as dissolved oxygen, nutrients, turbidity, suspended materials, water hardness, toxic substances, oil, and coliform. These indicators are compared to criteria (recommended limits) and standards (legal limits set to protect the public health) to determine water quality. Water quality criteria have been developed for its beneficial uses; use by people and domestic animals and aquatic organisms requires stricter water quality criteria than agricultural or industrial uses.

Water quality monitoring in and near the parks has been conducted by staff from the U.S. Geological Survey, the California Department of Water Resources, the California Department of Fish and Game, and Redwood National Park. Physical parameters (e.g., pH, temperature, alkalinity, and turbidity) are measured bimonthly in Redwood Creek and the Klamath and Smith Rivers. Chemical parameters (minerals, nutrients, and metals) were measured in streams by the California Department of Water Resources through 1996, but these measurements are no longer done on a regular basis. Biological parameters (e.g., benthic macroinvertebrates and fecal coliform) are measured in Redwood Creek and some of its tributaries, the Redwood Creek estuary, Mill Creek, and in area wells. A baseline inventory of the aquatic communities in the freshwater environments of the three state parks was undertaken for the 1984 *General Plan* (*Inventory of Features, App AL-II)*. When necessary, special water quality studies are conducted in the region by the North Coast Regional Water Quality Control Board. Also, the Yurok Tribe has attained status as a state under the Clean Water Act and now regulates clean water through permit issuance in the Klamath Basin under section 106 of the act.

Overall, the water quality in the parks meets or exceeds the water quality objectives established by the North Coast Regional Water Quality Control Board. Most levels of chemical, biological, and physical indicators in surface and groundwater supplies comply with primary and secondary water quality standards.

Nonpoint source pollution is the major water quality concern in the parks; it is widespread and difficult to define and has resulted from long-held land use practices. Activities that have adversely impacted water quality in the parks are logging, mining, construction, ranching activities, sand and gravel operations, and wastewater effluent disposal. Elevated sediment levels entering Redwood Creek have made the river wider and shallower with lower streambank heights; this increased sedimentation has degraded aquatic habitats and streamside vegetation and water quality has deteriorated. The impacts from land use activities decrease towards the north, with the Smith River having the least amount of water quality degradation in the parks.

Water quality indicators in RNSP waters are elevated during certain times of the year, in large part due to current and past land use activities. Elevated levels of calcium and bicarbonate in stream waters are derived from the weathering of the underlying Franciscan complex rocks and are more pronounced in areas that have been harvested for timber. Specific conductance and alkalinity tend to decrease in logged watersheds, such as Redwood Creek basin, because during peak flows, overland flow contains lower concentrations of soil-derived solids than in forested watersheds.

Chloride levels are high in the parks, originating from the ocean where they are transported as dry fallout, ocean spray, and rain. Seasonal variations in nitrate concentrations in the parks suggest that soil nitrate produced by fixation and organic decomposition early in the rainy season tends to wash out of logged watersheds and is taken up in tree growth in forested watersheds. In contrast, phosphorus, ammonium, and dissolved organic carbon accumulate in the soil during the dry season and are washed out and diluted as the rainy season progresses (NPS 1985, p. 16). Elevated levels of iron and manganese have been detected in the past in the water supply well at Prairie Creek Redwoods State Park, but the water is treated to comply with secondary water quality standards. High nutrient levels, such as phosphorus and nitrogen from ranching and farming activities, have been detected in the streams in the lower Redwood Creek valley.

Water Quantity

Water Rights

California recognizes surface water rights based on the prior appropriation and the riparian doctrines. California recognizes both correlative and appropriative rights for groundwater. The rule of correlative rights holds that the right to make an overlying use of water is not absolute but is relative to the rights of other overlying users. The rule is used primarily when the groundwater supply is insufficient to satisfy the needs of all sharing the water supply. In some cases, sharing is accomplished by prorating the supply on the basis of overlying acreage, although the recent trend suggests a more flexible approach. The prior appropriation doctrine allows the entity that first diverts water for beneficial use the right to use the water. Since December 19, 1914, exclusive means of making an appropriation was by permit from the California Water Resources Control Board. The requirement for a permit is applied to surface waters of subterranean streams flowing in known or definite channels. Under the riparian doctrine, water rights are subjected to the doctrine of reasonable use, which limits all rights to the quantity reasonably required for beneficial uses. Water must be used on the lands that are bordering the stream and may not be diverted out of the watershed.

The federal government may also hold reserved rights that arise from the purposes for which the land has been withdrawn from private ownership. When the federal government reserves land for a specific purpose, it also reserves, by implication, enough water unappropriated at the time of the reservation as is necessary to accomplish the purposes for which Congress or the president authorized the land to be reserved, without regard to the limitations of the state law.

Percolating groundwater is not within the jurisdiction of the California Water Resources Control Board. The owner of the land overlying a groundwater basin has the first right to withdraw water for a reasonable beneficial use on its overlying land. No permit is required for this type of appropriation.

Water Supply

Water supplies in the parks come primarily from wells and connections to community water systems. Public water system wells are issued water supply permits by the California Department of Health Services, and every water system is monitored monthly for mineralogical and bacteriological content. Surface water is the source of the water supplies for Mill Creek and Gold Bluffs Beach campgrounds, two residences and seasonal cabins at Del Norte Coast Redwoods State Park, and Aubell. Groundwater aquifers are the water supply for Prairie Creek campground and buildings (residences and offices), Wolf Creek Outdoor School, Jedediah Smith campground and two residences, Requa facilities, and the Redwood Hostel. RNSP headquarters in Crescent City, Arcata NPS offices, Camp Lincoln, the Howland Hill Outdoor School, the Redwood Information Center, and the South Operations Center and seasonal trailers are supplied water from municipal water supplies.

Crescent Beach and the Crescent Beach Education Center currently do not have potable public water supplies, but the parks have considered hooking up to the Crescent City Community Service District (Mike Lewis, California Department of Health Services, pers. comm. 2/26/97 and Frank Saylor, California Department of Health Services, pers. comm. 3/3/97).

Sewage Treatment

Wastewater is treated in a variety of ways in the parks. Effluent from the Crescent City headquarters and Arcata offices is treated at municipal wastewater treatment plants. The Requa maintenance facility has an onsite treatment plant. Other larger facilities, such as Redwood Information Center, have onsite septic tanks, leachfields, or chemical-type vault toilets. Smaller sites such as trailheads commonly have self-contained chemical toilets. Backcountry areas have either pit or self-composting toilets.

WETLANDS AND AQUATIC HABITAT

Redwood National and State Parks includes a wide variety of aquatic habitats and wetlands, ranging from headwater streams, large rivers, ocean shoreline, and deeper ocean waters. Abundant rainfall, a temperate climate, and varied topography create ideal conditions for the development of many different types of wetlands. Aquatic habitats, including sandy ocean beaches and rocky intertidal zones, are included in the descriptions of wetlands below.

Wetlands are defined by the National Park Service as any area classified as wetland habitat according to the U.S. Fish and Wildlife Service's *Classification of Wetlands and Deepwater Habitats of the United States* (Cowardin 1979). Wetlands types under this classification are referred to as “Cowardin wetlands.” According to this definition, a wetland has at least one of three attributes: undrained hydric soils, predominantly hydrophytic vegetation, or, if the substrate is nonsoil, the area is saturated with water or covered with shallow water at some time during the growing season of each year. The California Department of Parks and Recreation has used a less rigorous wetlands definition than the U.S. Army Corps of Engineers’ definition, which generally requires evidence of all three attributes. However, this joint plan proposes to define wetlands in the state parks consistent with those in the national park, which is according to the USFWS classification.

Hydric soils are soils formed in a wet environment. Hydrophytic vegetation is defined as vegetation typically found in wet areas rather than on upland or dry sites. The growing season is defined as the frost-free period. In Humboldt and Del Norte Counties the growing season is considered to be March through October by the

Natural Resources Conservation Service (formerly the USDA Soil Conservation Service), and year-round by the U.S. Army Corps of Engineers.

Wetlands types are taken from the 1987 *National Wetlands Inventory* topographic 7.5 minute quadrangle maps. The *National Wetlands Inventory* maps used the Cowardin classification. The classification begins with broadly defined “systems” — marine, estuarine, riverine, palustrine, and lacustrine— which are subdivided into more specific subsystems. The parks contain examples of all five systems. In the Orick area, where Redwood Creek runs at the base of forested hillslopes through its estuary to meet the Pacific Ocean, all five systems occur.

Each wetland system is divided into subsystems, which are subdivided by bottom type, or substrate, and water regime (duration and timing of inundation). Water regime can vary on a daily basis, such as in tidal wetlands; or a seasonal basis, such as normal high and low annual river flows; or an irregular basis, such as floodplains that are covered only during large floods. Areas that are classified as “irregularly exposed” are normally covered with water but sometimes dry — for example, rocky intertidal zones exposed only during very low tides.

The dominant vegetation — trees, shrubs, and emergents — is the most common (or in the case of trees, the largest) species or form of vegetation in a wetland. Emergents are erect, rooted, herbaceous wetland plants, excluding moss and lichens. The dominant vegetation has been used to define wetlands because it is easy to distinguish and does not change rapidly. Scrub-shrub wetlands include areas dominated by woody vegetation that is usually less than 20 feet (6 meters) tall. Scrub-shrub wetlands may eventually become forested wetland or may be relatively stable communities, such as willows along streams. Scrub-shrub and forested wetlands in the parks may be subdivided into broad-leaved deciduous or needle-leaved evergreen wetlands.

Representing the marine system in the parks are the rocky intertidal zone and sandy shoreline from Crescent Beach in the north down the coastal bluffs to Freshwater Spit beach in the south. These areas are periodically covered with water by waves and tides.

Estuarine wetlands are tidal habitats that are partly enclosed but may have periodic access to the open ocean. Ocean waters are at least occasionally diluted by freshwater runoff. Examples of the estuarine system are found where rivers and streams meet the ocean — at the mouths of the Klamath River and Redwood Creek and along Gold Bluffs Beach. Espa Lagoon, an estuarine wetland, has been converted into a coastal pond by the construction of the road, with its small, fixed invert culvert system, and by the stabilization of the beach due to introduced beach grass. RNSP estuarine wetlands may have sandy or unconsolidated bottom substrates or may be streambeds. The Redwood Creek estuary contains the largest variety of estuarine wetland types because of the variety of flooding regimes. Water regimes vary from irregularly flooded at the south slough to irregularly exposed for the north slough. The mouth of the Klamath also has an extensive system of associated wetlands.

Wetlands within the floodplains of larger streams and rivers may be classified as riverine if flowing water has a greater influence than groundwater. The parks contain a broad range of the riverine wetlands, from headwater drainages to small intermittent streams to large rivers, with a correspondingly broad range of bottom substrates and flooding conditions. Water is usually flowing in riverine wetlands. The riverine system includes wetlands that are bounded by a river or stream channel, except for some wetlands that are dominated by trees, shrubs, and persistent emergent vegetation. Some riverine wetlands are influenced by tidal action on a seasonal or permanent basis. The mouths of the Klamath River and Redwood Creek are examples of riverine wetlands that are influenced by ocean tides. Riverine wetlands include areas that range from permanently flooded to seasonally flooded.

Riverine wetlands in the parks include intermittent headwater streams in the channels at the bottom of steep, well-drained slopes. Smaller streams either drain into larger streams or rivers, for example Ah Pah Creek, Boyes Creek, and

Bridge Creek, or directly into the Pacific Ocean. Cushing Creek, Nickel Creek, Squashan Creek, and Major Creek are examples. Riverine wetlands are very common around Hiouchi and Jedediah Smith Redwoods State Park. Riverine and palustrine (see below) wetlands are very common in the parks because the steep, dissected topography; abundant rainfall, and temperate climate create streams and rivers bordered with vegetation.

Palustrine wetlands are defined as nontidal areas dominated by trees, shrubs, and persistent emergent vegetation. These wetlands best fit the common notion of wetlands and have traditionally been called marshes, swamps, and bogs. Small, shallow, permanent or intermittent bodies of water called ponds are also classified as palustrine. Areas only temporarily flooded at the highest water levels are included in the palustrine system. Among the areas classified as palustrine wetlands are the coastal ponds at Crescent Beach; some of the diked and impounded agricultural lands near the Redwood Creek estuary; and two artificial impoundments created for logging mills — Marshall Pond on Richardson Creek that formerly drained into the south bank of the Klamath near the mouth, and the Lagoon Creek pond near False Klamath Cove.

Marshall Pond contains an estimated 5–10 acres of palustrine wetland around its edges. The pond was formed by damming Richardson Creek to create a log holding pond for an adjacent lumber mill that used to operate there. Richardson Creek enters the Klamath River about 2 miles upriver from the Pacific Ocean. Wetland values of Marshall Pond include habitat for fish, amphibians, breeding waterfowl, and other wildlife, and recreational and aesthetic benefits for hikers passing the pond on the Flint Ridge portion of the Coastal Trail. A 1988 survey of the pond by NPS biologists found four fish species, three of which were introduced warm-water fish. The only native fish was the three-spine stickleback.

Salamander larvae, steelhead or coastal cutthroat, coho salmon, and two other native fish were obtained by electroshocking the riffle and pool habitats in Richardson Creek. Local American Indians report (Redwood National Park memo dated 3/26/85) that Richardson Creek once supported a higher salmonid population than with the dam in place. Waterfowl observed at the pond include rails, wood ducks, ringneck ducks, and hooded mergansers. Wood ducks breed at the pond.

The Lagoon Creek area is estimated to include about 5 acres of palustrine wetland. Lagoon Creek is scenic and provides wildlife habitat; it also is used for recreational fishing. The pond is stocked with rainbow trout by the California Department of Fish and Game under an agreement between the national park and the State Wildlife Conservation Board.

Lacustrine wetlands are defined as areas greater than 20 acres lacking trees, shrubs, or emergent vegetation. The lacustrine system is represented only by Freshwater Lagoon. The natural processes and functions of Freshwater Lagoon have been greatly impacted by the construction of Highway 101 across its spit and the installation of a culvert to maintain water levels below the level of the highway surface. This lagoon can no longer breach, overwash is severely limited by fill on the spit, and subsurface flow between the lagoon and ocean has been affected by soil compaction during road construction and the introduction of earthen fill across the spit.

PLANTS

Note: The primary reference for this section is Olive et al., (CDPR 1982 & 83; also see appendix F).

There are many ways to classify vegetation. In this document, vegetation is grouped broadly by habitat types or communities that are generally based on the dominant plant species. A species or group of species, such as grasses or trees, may be dominant either in terms of numbers present or in area covered or even the size of the plant. The dominant species in a forest is often the tallest tree species.

Forests are the predominant vegetation type in the parks, with prairies and oak woodlands, brushlands, and coastal plant communities also present. The serpentine soils that occur in the northern parts of the parks often support

The Coast Redwoods

Redwoods are the dominant species in the parks and the reason why Redwood National and State Parks were established — to preserve them. The following provides some information about these wonderful trees.

Fossil redwoods have been found in rocks estimated to be more than 160 million years old. Redwoods were formerly widely distributed throughout the northern hemisphere. With long-term climate and topographical changes, redwoods gradually were restricted to areas of relatively mild climate. The range of the coast redwood (Sequoia sempervirens) in modern times extended from the extreme southwest corner of Oregon southward along the summer fog belt of the California Coast Range to the Santa Lucia Mountains of Monterey County, a zone 450 miles long and up to 40 miles wide.

The coast redwood reaches the greatest height of any known modern tree, at more than 350 feet. Redwoods are much taller yet smaller in diameter than the closely related giant sequoias (Sequoiadendron gigantea) found in the Sierra Nevada Mountains of central California. Coast redwoods are not known to exceed 21 feet in diameter at breast height. The greatest age known to have been attained by a coast redwood is 2,200 years. The average age of trees in old-growth stands ranges between 400 and 800 years old.

Coast redwoods in Redwood National and State Parks occur from sea level to ridgetop. Redwoods grow at elevations up to about 3,000 feet. Trees growing near the sea must contend with strong ocean winds and wind-borne salt. Redwoods have a low tolerance for both conditions. The best development of pure dense stands of coast redwoods throughout their range occurs in Humboldt and Del Norte Counties, on alluvial deposits and riverbottoms that are sheltered from coastal winds.

The tallest redwoods grow on alluvial flats. The growing season in alluvial stands is year-round, with maximum growth from late spring to early summer. On upland slopes, trees are shorter, the diversity of other tree species is greater, and the understory is more shrubby. The long life span and massive size of redwood trees result in forests of the greatest accumulation of weight of living material known (Franklin 1988).

Redwood trees reproduce both by seeds and by sprouting. Sprouting is strongly developed in redwoods and contributes to its ability to persist through disturbance. Wind-blown branches, fallen trees, burls, broken tops, and fire-damaged trees all have the ability to sprout.

Redwood sprouts grow extremely rapidly, followed by slower growth (up to 14 inches in height annually) of seedlings for four or five years, then another rapid growth period for up to 20 years. Large mature trees grow an average of 4–5 feet in height annually.

different vegetation than the surrounding areas, including rare or unique species.

The Redwood Forests

The redwood forest is dominated by coast redwood *(Sequoia sempervirens)* and Douglas-fir *(Pseudotsuga menziesii)*. Associated species depend on local conditions such as whether a site is upland, riparian (streamside), alluvial (along a floodplain), or close to the ocean. Other coniferous trees are grand fir *(Abies grandis)*, Sitka spruce *(Picea sitchensis)* in lowland and coastal areas, and western hemlock *(Tsuga heterophylla)* in moist habitats. Conifers other than redwood may be the dominant species in some forest stands where soil, temperature, moisture, and ocean salt-spray do not favor redwoods. Old-growth forests occupy about 39,000 acres in Redwood National and State Parks.

Hardwood species are generally overtopped by conifers in redwood forests but occasionally dominate a stand. Major hardwoods are tanoak *(Lithocarpus densiflora)*, madrone *(Arbutus menziesii)*, bigleaf maple *(Acer macrophyllum)*, California bay or laurel *(Umbellularia californica)*, and red alder *(Alnus rubra)*. Except for madrone, all these hardwoods occur in both riparian and upland areas.

Moist lower slopes have the lushest understory found in redwood forest communities. The dominant understory species of the redwood forest are oxalis *(Oxalis oregana)* and sword fern *(Polystichum munitum)*. Other common understory plants are rhododendron *(Rhododendron macrophyllum)*, huckleberry *(Vaccinium* spp.*)*, salal *(Gaultheria shallon)*, azalea *(Rhododendron occidentale)*, and several types of berry *(Rubus* spp. and *Ribes* spp.*)*. Middle and upperslope positions are characterized by evergreen shrubs (salal, rhododendron, and huckleberry).

The presence of fog is often associated with the range of redwoods, but no known causal relationship exists. The summer fogs reduce insolation (how much sunlight reaches an area) and provide a moisture source during generally rainless summers. Inland and upslope away from the summer fog zone, forests become drier and the redwoods become less numerous.

Dry Forests

Dry forests, which include mixed evergreen forest, Jeffrey pine, and knobcone pine forests, are found in the eastern parts of Jedediah Smith Redwoods State Park. In the Redwood Creek basin, dry forest types occur from the Lacks Creek drainage and upstream.

The mixed evergreen forest found inland from the redwood forest is dominated by Douglas-fir, tanoak, and madrone. California bay, bigleaf maple, chinquapin *(Chrysolepis chrysophylla)*, canyon live oak *(Quercus chrysolepis)*, and poison oak *(Toxicodendron diversilobum)* are also common in this forest type.

The Jeffrey pine/chaparral/knobcone pine vegetation type includes several distinct vegetation types that are grouped here because they are localized in the Little Bald Hills, an area of about 1,300 acres in the eastern portion of Jedediah Smith Redwoods State Park and adjacent national park. Despite almost 100 inches of annual precipitation here, these communities have sparse vegetation due to serpentine soils, which have high concentrations of heavy metals such as magnesium and few nutrients available for plants because of high pH and poor water holding capacity. These harsh growing conditions have resulted in the development of specialized plant communities with many unique plant species.

The driest ridgetops are occupied by widely scattered Jeffrey pine *(Pinus jeffreyi)*, while a chaparral vegetation type downslope is dominated by manzanita *(Arctostaphylos* spp.*)*, golden chinquapin *(Chrysolepis chrysophylla)*, rhododendron *(Rhododendron macrophyllum)*, huckleberry oak *(Quercus vaccinifolia)*, and other evergreen shrubs, interspersed with stands of knobcone pine *(Pinus attenuata)*. Port-Orford-cedar *(Chamaecyparis lawsoniana)* is found here.

The knobcone pine vegetation type in the parks is a dense forest of small-diameter, mostly even-aged pines. Knobcone pines may be restricted to serpentine soils and are subject to frequent fires because of their association with other fire-dependent vegetation, xeric growing conditions, and early senescence, which adds to the fuel layer. Knobcone is a successional stage that in the absence of fire gives way to Douglas-fir, madrone, and tanoak. Based on tree fire scar examination and post-fire regeneration, the last known fire in the knobcone pine vegetation type was about 1940, according to the 1994 Redwood National Park *Fire Management Plan*.

Prairie and Oak Woodland Vegetation

The most extensive prairie vegetation type in the parks is in the Bald Hills, on the eastern watershed divide of Redwood Creek. The Bald Hills prairies are a distinct vegetation community as identified by Holland (1986) but the term "Bald Hills" in the national park includes a complex mosaic of vegetation types including prairies, Oregon white oak *(Quercus garryana)*) woodlands, and coniferous forest. The Bald Hills include about 1,500 acres of Oregon white oak woodland and 3,900 acres of prairie. Smaller prairies or grasslands include those at Davison Ranch, Elk Prairie and Ossagon Prairie in Prairie Creek Redwoods State Park, and Deer Meadow in Jedediah Smith Redwoods State Park. Some of these prairies may be the result of human activity, including tree cutting, livestock grazing, and repeated burning.

The extent of the Bald Hills prairies is determined by a number of factors, including soil type, slope, aspect, landform position, present and past climate, plant succession processes, and fire history. The extent of the prairies may be determined by physical and chemical soil conditions rather than climate, although the prairies tend to be beyond the limit of coastal fog (Holland 1986). The prairies occur in areas of clayey fine-textured soils on ridge crests, usually a few miles from the coast in the zone of mixed evergreen and coniferous forests, in patches from Sonoma County, California, to southern Oregon.

Humans may have had a profound influence on the ecological processes thought to have perpetuated the Bald Hills prairies over thousands of years (Popenoe et al. 1992). Before the arrival of Euro–Americans around 1850, American Indians traditionally used fire to increase the amount of seeds, basketmaking materials, and forage for deer and elk. Euroamericans brought livestock and nonnative pasture plants and built roads. The roadsides were colonized by woody species. By the middle of the 20th century, the deliberate burning of grasslands had ceased. Douglas-fir, which is killed by fire in its first few years, was able to establish in increasing numbers. The Douglas-fir grew very rapidly in the moist, mild climate, and began to take over large areas of prairie and oak woodland. RNSP staff instituted a program of prescribed fires (planned ignitions) and cutting to remove encroaching Douglas-fir and restore fire as a process.

Native grasses and forbs make up two-thirds of the species in the Bald Hills, but nonnative pasture grasses predominate in cover. Three native species are common: a sedge *(Carex tumicola)*, California oatgrass *(Danthonia californica)*, and blue wildrye *(Elymus glaucus)*. The most common nonnative species are tall oatgrass *(Arrhenatherum elatius)*, sweet vernal grass *(Anthoxanthum odoratum)*, velvet grass *(Holcus lanatus)*, dogtail *(Cynosurus echinatus)*, soft chess *(Bromus hordeaceus)*, plantain *(Plantago lanceolata)*, and sheep sorrel *(Rumex acetosella)*.

Oregon white oak woodlands are found on drier, warmer slopes and canyon bottoms in the Bald Hills. Black oak *(Quercus kelloggii)*, California bay, and big-leaf maple are found near rock outcrops and stream channels. Douglas-fir occurs on rockier sites. White oak stands with older, larger-trunked, wide-crowned trees surrounded by younger, narrow-crowned trees have burned less frequently (James Popenoe, RNSP soil scientist, pers. comm., 12/3/97).

Brushlands

Brushlands dominated by shrubby species occur among other types of vegetation throughout the parks where harsher conditions such as drier, gravelly, or sandy soils occur, or in areas subject to high velocity floodwaters such as the floodplain of the Smith River. The most common brushland species include manzanita *(Arctostaphylos* spp.*)*, *Ceanothus*, coyote brush, mountain mahogany *(Cercocarpus betuloides)*, and poison oak.

Coastal Vegetation

Coastal vegetation types include coastal strand, vegetation that grows on sand dunes, and coastal shrub. Coastal vegetation is subject to wind and salt spray. The sandy soils are well drained and may not be stable. Some areas exhibit wind pruning because of strong, constant winds. Two sensitive plant species, the pink sand verbena *(Abronia umbellata* ssp. *brevifolia)* and Wolf's evening primrose *(Oenothera wolfii)*, occur in coastal vegetation types.

Coastal strand is dominated by low-growing salt-tolerant plants like sand verbena (*Abronia latifolia*) and sea rocket (*Cakile maritima*) scattered throughout the sandy areas. This vegetation may be washed by storm waves during winter high tides.

Sand dunes occur at Crescent and Gold Bluffs Beaches and at Freshwater Spit. The vegetation that grows on dunes along the ocean is subject to incessant desiccating, salt-bearing breezes. Shifting sands around alien European beach grass are invaded by species tolerant of sand cover, which are then able to spread over larger areas and stabilize those areas. This creates suitable habitat for species that are not tolerant of sand burial — first low-growing or herbaceous vegetation and then shrubs and trees. At Gold Bluffs Beach, succession is visible as beach grass on dunes facing the ocean are being invaded by lupine, coyote brush, and Sitka spruce on the back dunes. As succession proceeds, alder groves have become established on the alluvial flats created by the numerous creeks that drain from the bluffs onto the dunes. At Gold Bluffs Beach, sand deposition and stabilizing effects of alien European beach grass may have allowed dunes to form. According to historical reports, waves broke on the bluffs; there were no beaches or dunes.

Coastal shrub generally occurs on a narrow strip between dunes and coastal coniferous forest. Although subject to less wind and salt spray than dunes and strand communities, vegetation may still exhibit wind pruning and may take on a low or prostrate form. Coastal shrub includes areas dominated by evergreen shrub species, wind-pruned trees, or low-growing shrubs intermixed with herbaceous species and grasses. Coyote brush *(Baccharis pilularis)*, salal *(Gaultheria shallon)*, salmonberry *(Rubus spectabilis)*, lupine *(Lupinus* spp.*)*, and oceanspray *(Holodiscus discolor)* are common species. The most common wind-pruned trees are Sitka spruce and red alder.

Plant Succession and Natural Disturbances

Ecological succession is a sequence of changes in the number or type of plant species found in an area. Each succeeding associated set of plants is called a sere, or seral stage. An associated set of plants (a plant community) that remains relatively stable through time and is self-sustaining even in the presence of some disturbance is called a climax community, and the vegetation is called climax vegetation.

Both natural and human-caused disturbances can create changes in plant communities and alter succession. The effects of naturally occurring fire on the redwood forest ecosystem are covered in this section. The next section covers the effects of human-caused fires and fire suppression.

Following disturbance, whether natural or human-caused, a forest matures through various stages and acquires a set of characteristics that define it as old growth. Seral stages in forests include stand initiation, stem exclusion, understory reinitiation, and old growth. The stand initiation stage covers invasion of the forest opening. Stem exclusion describes the stage where all available space is occupied by invaders. In understory reinitiation, gaps reappear in the canopy and allow light to penetrate; understory species can then grow. Old growth is defined in this sequence as the stage when the original invading trees are beginning to be replaced by young trees again (Oliver 1981). Old-growth redwood and Douglas-fir forests are characterized by large gaps between old trees, many age classes of trees from young to old, a multistoried canopy, large snags (dead trees), and large downed logs.

RNSP staff is managing the redwood forests to return natural processes of ecological succession to these areas. Natural physical disturbance factors affecting the redwood forest are flooding, fire, wind, and slope instability. The Bald Hills prairies and oak woodlands are managed to restore processes necessary for their perpetuation. Bald Hills prairies and oak woodlands are being invaded by Douglas-fir forest, probably as a result of fewer natural and human-set fires.

Coastal redwood is not dependent on fire for cone sprouting as is the giant sequoia. The regeneration of redwood forests was once believed to depend on disturbances such as fire or flood (Stone 1966 and 1967; Stone and Vasey 1968). Analyses of different ages of trees in logged stands have shown that redwood can reproduce enough to keep the population growing, even in the absence of catastrophic disturbance (Veirs 1980).

Flooding has both positive and negative effects on streamside forests. The tallest redwood trees grow on the alluvial flats adjacent to the major streams. Alluvial flats are the product of repeated flooding and can be both produced and removed by major floods. Fine-grained silts and abundant moisture in alluvial flats encourages seedling establishment. Coast redwood is favored over other tree species in the alluvial flats because of its ability to tolerate flooding. It adapts to successive inundation by growing a new set of surface roots in the new soil layer.

Fluctuations in the water table can adversely affect roots and seedlings in alluvial flats. Aggradation of streams can accelerate bank erosion and directly topple trees or undercut banks and expose or weaken roots; aggradation can also raise the water table and drown tree roots. The deposition of gravel can smother seedlings. Permanent lowering of the water table can preclude redwood survival by removing needed moisture from the roots.

Moist coastal redwood forests in low elevations, especially alluvial stands, have a lower incidence of fire than upland drier Douglas-fir forests. Fires that are not intense enough to open the canopy favor the regeneration of western hemlock but usually eliminate the older trees. Douglas-fir establishment through seedlings is infrequent under a closed canopy. Douglas-fir appears to be favored by fires of great intensity that open the canopy and allow light and heat to penetrate to the forest floor.

Lightning fires are not frequent near the coast in northern California, but their importance as an ignition source increases with elevation and distance from the ocean. Intense fires occur at intervals of greater than 500 years in more mesic lowland sites, 150–200 years on mid-elevation and coastal upland slopes, and 50 years on hotter, drier inland slopes (Veirs 1980). Other research suggests that fires in mid-elevation redwood forests may occur as frequently as every 10 years (Brown and Swetnam 1994).

Wind affects redwoods by breaking off stems and branches and creating windfalls that may include the roots. Heavy winter precipitation saturates and softens soils, and intense winds then topple shallow-rooted redwoods. Openings in the canopy also increase the likelihood of windfall. Soil compaction contributes to vulnerability to windthrow (trees being uprooted by wind).

Landslides are another physical process that can topple trees and create forest openings. There are examples of landslides where trees have been toppled near the Tall Trees Grove .

Existing and Past Human-Caused Disturbances

Logging has had the greatest impact on the natural vegetation in the parks. Most of the timber harvesting in what is now Redwood National Park occurred between 1950 and 1978. The national park contains between 45,000 and 50,000 acres (a little less than half the total acreage of all four parks) of second-growth forests that are in various stages of regrowth. The term second growth is used here for forests or stands that regrew after logging. Some stands may actually have been cut more than once. Most of the second-growth forests in the national park were added in the 1978 park expansion and are in the Redwood Creek basin. Of the more than 30,000 acres within the three state parks, about 4,400 acres have been logged since the late 1800s.

Vegetation in second-growth stands depends on the dominant vegetation at the time of cutting, how long ago the area was cut, which species were harvested, whether the cutting was selective or clearcut, the physiography of the cut area (slope, aspect, soil type, elevation), and whether the cutover areas were replanted and the method of replanting (seeding or planting seedlings).

Logging in old-growth was once primarily by the seed-tree method, where selected trees were left as a seed source for new growth and removed later. The dominant timber harvest method in the Redwood Creek basin in what later became part of the parks was clearcut logging combined with seeding or planting to ensure revegetation, followed by thinning to produce higher value timber in a short period. Thinning is the usual practice in timber management to ensure that the plantings reach merchantable size in a shorter period of time.

The general pattern of plant succession after timber harvest begins with short-lived annual and biannual herbs in the first three years followed by the development of shrub communities, either from remnant plants that have survived timber harvest and flourished or from invading species capitalizing on the disturbed environment. Eventually, reduced light levels eliminate all but the most shade tolerant species.

Future dominant tree species are usually present as seedlings in each early succession type. Following logging, short-lived weeds dominate for about five years. Hardwood shrubs become abundant in 6 to 10 years following logging and dominate for 11 to 20 years.

In the redwood/Douglas-fir forests in the parks, thickets of red alder developed after timber harvest, especially on lower slopes near streams and other wet areas. These thickets are followed by Douglas-fir and redwood in the understory as the site stabilizes. Alder dominance may continue for 50 to 80 years. If disturbance continues, as might occur in landslide areas due to the presence of roads or unstable slopes, alder may replace itself.

On drier sites, brush may invade, especially blueblossom *(Ceanothus thyrsiflorus)* and coyote brush. Both alder and blueblossom are nitrogen fixers and contribute to the productivity of the soil. Alders colonize naturally from around streams at the base of a slope in response to disturbance by landslides and flooding, whereas blueblossom colonizes ridges and upper slopes in response to fire.

Old-growth forests differ from unmanaged second-growth forest in the numbers of individual trees, numbers of tree species, and age structure of trees. Second-growth stands feature trees of the same age. These even-aged stands are very different from old-growth stands that contain a variety of different age classes, from seedlings to old trees.

There are more Douglas-fir trees relative to the number of redwood trees in the second-growth forests than in uncut forests in the parks (Stephen Underwood, RNSP supervisory botanist, pers. comm., 12/96). Following timber harvest, the stands were seeded or planted with a mix of coniferous species but never thinned. Because Douglas-fir survives better than other species in a planting mix, many second-growth stands are almost pure Douglas-fir. The density of trees in stands of 20-year-old second-growth forest ranges from 1,750 to 2,350 trees per acre (Cussins 1994, Veirs 1986, Veirs and Lennox 1981). Some second-growth stands in the parks contain 10,000 small Douglas-fir trees per acre, with very few redwood trees (Veirs 1986). In contrast, old-growth stands contain between 10 and 35 large trees, some of which may be Douglas-fir (Veirs 1982).

Forest stands sampled in the parks exhibit a ratio of redwood to Douglas-fir in the canopy of old-growth stands typically ranging from 10:1 to 3:1, depending on individual stand history. In young second-growth stands, the situation is reversed, with Douglas-fir outnumbering redwood by a factor of 10:2, depending on slope positions and aspect. Early experiments on thinning 25-year-old second-growth plots in the national park demonstrated that thinning can produce stands with species ratios similar to untreated 60-year-old stands (Veirs and Lennox 1981).

The role of fire in managed forests differs from its role before Euroamericans intervened into the fire history of an area (CDPR 1982 & 1983, Olive et al.). Burning by American Indians was eliminated, and a vigorous program of suppression of both man-caused and lightning-caused fire was instituted. Fire suppression has probably had little or no effect on bottomland redwood forests or in the fire potential there, except in drought years (Veirs 1972 and 1980). Suppression has had a greater effect in upland mixed evergreen and Douglas-fir dominated forests where drier conditions allow lightning-caused fires to spread. Fire suppression also increases the amount of down wood that acts as fuel, so that when a fire does start, it is likely to be much more intense in those areas where fires have been suppressed (CDPR 1982 & 1983, Olive et al.).

American Indian burning was conducted in specific areas in the redwood region, including in and around higher elevations in the grasslands and oak woodlands above the forests (CDPR 1982 & 1983, Olive et al., p. 33.). The purpose was to produce seeds and basketmaking materials, including five-fingered ferns, spruce root, and hazel, as well as to create forage for deer and elk that were hunted for meat. Burning in tanoak groves cleared the ground beneath the oaks so that acorns could be collected (Schenck and Gifford 1952).

These fires, under most conditions, would only carry in the fine fuel, such as grass, and would not spread in the coarser and moister forest fuels. However, with the drying winds and lack of rain in late summer, prairie fires can spread though upland forests.

American Indian burning was apparently most influential upon the vegetation at higher elevations and south-facing slopes, such as the prairies and oak woodlands above the forest (CDPR 1982 & 1983, Olive et al.). American Indian burning in the Bald Hills woodlands and prairies probably had a major influence on fire frequency in the adjacent redwood forest, but the magnitude of these burns in comparison to lightning-caused ignitions cannot be quantified with the available data.

Timber harvest increases the amount of ground debris that serves as fuel. Harvested stands were routinely treated for slash removal, often through controlled burning. Second-growth forests that were not thinned as intended under a commercial management regime have a greater chance of large and intense fires than old-growth forests, which tend to be cooler and have less fuel available. Second-growth forests in the parks contain a greater amount of fuels that allow a ground fire to move up into a canopy.

Harvested areas open up the forest and increase the susceptibility of wind effects. Wind effects include limb breakage, tree mortality, and windthrow (trees uprooted or breaking due to force of wind). Potential for wind effects is greatest where clearcuts are right up to RNSP boundaries.

Nonnative plants, also called exotic or alien species, quickly colonize disturbed habitats throughout the parks but may also invade undisturbed native vegetation. Estimates of the percentage of nonnative range from about 20% to 25% of the total of about 850 species.

Several factors have contributed to the replacement of native species by nonnatives in the parks — the introduction of highly competitive nonnative species, the increase in grazing, the elimination of annual fires, the cultivation of food and horticultural plants, ground disturbance from timber harvest, windborne seeds, intentional introductions, and the presence of highway corridors.

Old-growth redwood forest is too shady for some nonnative plant species. Timber harvest opens the canopy and allows the invasion of species such as pampas grass *(Cortaderia jubata)*. Regrowth of the forest shades the ground, causing some nonnatives like pampas grass to die out. Other invasive nonnatives such as English ivy *(Hedera helix)*, English holly *(Ilex aquifolium)*, and cotoneaster *(Cotoneaster* spp*.)* survive in the shade and displace native species.

Soils along roads are particularly susceptible to invasion by alien plants. The soils are continually disturbed for road maintenance and also have a continual source of seeds from vehicles, maintenance equipment, and gravel shipments.

Some of the nonnative plants disrupt natural ecological processes, degrade native wildlife habitat, and displace native vegetation. Some nonnative plants have been assigned high priority for control in the parks. Tansy ragwort *(Senecio jacobaea)* and Canada and bull thistle *(Cirsium arvense* and *C. vulgare)* are unpleasant, unpalatable, and/or toxic to wildlife. European beach grass *(Ammophila arenaria)* degrades native plant and snowy plover habitat by trapping sand and burying native plants. European beach grass, pampas grass *(Cortaderia jubata)*, Scotch broom *(Cytisus scoparius)*, French broom *(Genista* *monspessulana)*, and Himalaya berry *(Rubus discolor)* shade out lower growing native vegetation. In contrast, English holly, coton-easter, and English ivy are slow-growing, shade-tolerant species that invade the understory of native forests and gradually outcompete the native plants. Recently discovered nonnative species — purple knapweed *(Centaurea* spp.*)*, a noxious weed related to star thistle, and Peruvian lily *(Alstromeria aurantiaca)*, an aggressive plant that has escaped from cultivation (garden escape), are being targeted for control.

Some plant species found in the parks are native to California but not to the north coast region or the parks. These species have become established in the parks through planting for commercial harvest or for horticultural purposes. Monterey pine *(Pinus radiata)* and Monterey cypress *(Cupressus macrocarpa)* are examples. Neither of these species occurs naturally in northwestern California, but both thrive when planted. Monterey pine was aerially seeded in 1967 in about 180 acres in the Tom McDonald Creek area in the Redwood Creek basin following timber harvest. The pine was also planted along Highway 101 in some areas in the parks. Research on the stand in the Redwood Creek basin suggests that, in the absence of fire, the pine will die out because seedlings will not compete with native trees.

Nonnative plants are controlled under a program described in the NPS 1995 *Exotic Plant Management Plan*, the 1985 *State Redwood Parks General Plan,* and the California Department of Parks and Recreation's *Resource Management Directives.* The national park plan describes objectives, strategies, and control techniques; assesses threats; and assigns a priority for species to be controlled. Control efforts are directed where there is significant risk to other species or ecological processes and where successful control is both economically and biologically likely. Methods of control on unwanted plant species include mechanical removal by hand or with tools; burning to remove standing plants and perhaps sterilize the soil of seeds; and chemical control as a last resort. Often a combination of control techniques is necessary. Each location and target species requires a specific prescription and usually repeated attempts for successful control.

WILDLIFE

Animal species diversity is lower in the upland redwood forest community, especially the younger-aged redwood forest community, in comparison to other plant communities (such as riparian forests) because of lower plant diversity and less structural complexity in the canopy. The mosaic of forest, prairie, streamside, aquatic, and coastal areas provides habitat diversity for wildlife.

The moist cool coastal environment of the old-growth forest favors salamanders and frogs over lizards and snakes, which are more common in the drier prairies and oak woodlands. Pacific treefrogs *(Hyla regilla)* are common in marshes, meadows, woodlots, brush, and disturbed areas. Northern red-legged frogs *(Rana aurora aurora)* are common in some parts of the parks. These frogs use the coastal ponds inland from Crescent Beach and other open bodies of freshwater associated with wetlands and sloughs for breeding. The closely related California red-legged frog *(R. a. draytonii)* that inhabits areas south of the parks is listed as a threatened species. The relationship between these two subspecies north of Marin County, California, is poorly understood (*Federal Register* 1994). The northern red-legged frog is declining in British Columbia, Washington, and Oregon (Hayes and Jennings 1986); many of the coastal watersheds that the northern red-legged frog inhabits have sustained significant alteration related to timber harvest (California Department of Forestry and Fire Protection 1988). Because of the threat to the northern red-legged frog in the northern part of its range, as well as to amphibian populations throughout California, the parks' populations of red-legged frogs should be monitored (California Department of Fish and Game 1994; Sean J. Barry, UC Davis School of Medicine, pers. comm. 8/18/97).

The salamanders include the northwestern salamander *(Ambystoma gracile)*, Pacific giant salamander *(Dicamptodon tenebrosus)*, southern torrent salamander *(Rhyacotriton variegatus)*, the rough-skinned newt *(Taricha granulosa)*, Del Norte salamander *(Plethodon elongtus)*, Ensatina *(Ensatina eschscholtzii)*, three species of arboreal salamander *(Aneides)*, and California slender salamander *(Batrachoseps attenuatus)*.

Reptile diversity is generally low in old-growth forests, and there are fewer lizards in these areas as well. Pond turtles occasionally occur in streams and ponds formed by logging. The highest diversity of snakes and lizards is found in drier upland areas of Jedediah Smith Redwoods State Park and in the Bald Hills prairies and oak woodlands. Northwestern and western terrestrial garter snakes *(Thamnophis ordinoides* and *T. elegans)*, racers *(Coluber constrictor)*, and gopher snakes *(Pituophis melanoleucus)* are the most common snakes. Western fence lizards *(Sceloporus occidentalis)* and northern fence lizards *(Elgaria coeruleus)* are the most common lizards.

More than 400 species of birds have been reported in the parks, 200 of which are known to breed in the parks. Slightly more than 100 of these species are neotropical migrants (birds for which the majority of the population winters south of the Mexican border). Most of these neotropical migrants are songbirds, which have only recently been recognized as seriously declining on their breeding and wintering grounds.

The parks have suitable habitat for a number of small mammals whose range is confined to moist, dense, coniferous forests and associated coastal habitats in the Pacific Northwest. These include the marsh shrew *(Sorex bendirii)*, shrewmole *(Neurotrichus gibbsii)*, coast mole *(Scapanus orarius)*, mountain beaver *(Aplodontia rufa)*, California red-backed vole *(Cleithronomys californicus)*, red tree vole *(Arborimus longicaudus)*, Townsend's vole *(Microtus townsendii)*, and Pacific jumping mouse *(Zapus trinotatus)*. These species have been recorded in all three state parks, except for the shrew, red tree vole, and Townsend's vole. The latter two species have been observed in Jedediah Smith Redwoods State Park. There are records of the shrew and the red tree vole from Del Norte Coast Redwoods State Park from studies done in conjunction with the realignment of the highway at Cushing Creek.

In addition to species confined to the moist coastal habitats, other small mammals include several species of deermice *(Peromyscus* spp.), dusky-footed woodrat *(Neotoma fuscipes*), western harvest mouse **(***Reithrodontomys megalotis***)**, little brown bat *(Myotis lucifugus*), Yuma myotis (*Myotis yumanensis*), California myotis (*Myotis californicus*), and Townsend’s big-eared bat *(Plecotus townsendii).*

Species known to occur in the parks that are found in higher numbers in old-growth forest are Pacific giant salamanders *(Dicamptodon tenebrosus)*, marbled murrelets *(Brachyramphus marmoratus)*, and flying squirrels *(Glaucomys sabrinus)*. The presence of these species can be used as an indicator of ecosystem health.

Large mammals that may be spotted by visitors are the gray fox, coyote, black bear, river otter, bobcat, mountain lion, black-tailed deer, Roosevelt elk, seals, and sea lions. Gray whales are also seen from ocean overlooks or from coastal beaches on their annual migrations between northern feeding grounds and calving areas off the coast of Baja California, Mexico.

Clearcutting of forests in the Coast Range has provided artificial clearings suitable for Roosevelt elk, black bear, and black-tailed deer. These cutover lands in and around the parks provide excellent habitat and resulted in an increase in numbers during the period of intensive logging. New plant growth is abundant on clear-cut forest lands, and it is more nutritious than older plant material. Use of second-growth forested areas by elk, deer, and black bear has declined relative to when these areas were first cut.

Currently in Humboldt and Del Norte Counties, elk appear to be expanding their range from population centers located on both private and public lands near Big Lagoon, along Prairie Creek, along the Gold Bluffs, in the lower Redwood Creek area, and in the Bald Hills (Rick Wallen, RNSP fish and wildlife biologist, pers. comm., 12/12/97). Roosevelt elk are commonly seen in meadows and open pastures along Highway 101 near Orick and in Elk Prairie and along Gold Bluffs Beach in Prairie Creek Redwoods State Park. In 1984 there were four herds in that park, totalling about 200 animals. Elk have been noted recently in

Jedediah Smith Redwoods State Park and vicinity.

The Gold Bluffs Beach herd uses beach dune areas and coastal spruce forests for cover, mating and calving areas, and forage. In the Bald Hills, the herd is associated with the prairies, especially in the spring and fall. Elk use of the nearby second-growth forest is greatest during the mating season in September and October. Habitat characteristics important to elk include forage areas, mating and calving grounds, travel corridors, resting areas, and escape cover.

The opportunity to see elk is one of the main attractions of the parks. Elk Prairie in Prairie Creek Redwoods State Park is well known for its elk herd. Their large size, impressive antlers, and habit of frequenting open pastures make Roosevelt elk the most prominent animal in the parks. Visitors driving through Prairie Creek Redwoods State Park (Newton B. Drury Scenic Parkway) or along Highway 101 near Davison Ranch often stop to watch or photograph the elk. There are no reports of elk seriously injuring humans, even though humans approach closely despite signs warning of potential danger from these wild animals.

There are historical reports of “bands of hundreds, perhaps thousands” of elk in the area in 1850–52. Elk were killed in great numbers in California for food and hides as settlement occurred after the Gold Rush of 1848. Conversion of elk habitat to croplands further reduced numbers. Elk persisted in coastal northwestern California where dense forest and brush and difficult access provided refuge. Humboldt County elk became abundant again a hundred years later, by 1964. In 1979 one researcher estimated the California Roosevelt elk population to be 1,000 to 1,300 with roughly half of those in and around the parks (Mandel and Kitchen 1979).

Present-day mortality of elk is due to poaching, accidental death (mostly by motor vehicles), and malnutrition. Predation and disease do not appear to be major factors. Occasional special hunts on adjacent nonpark lands are allowed by the California Department of Fish and Game for herd reductions. In five special hunts between 1964 and 1984, 300 permits were issued and 222 elk were taken. The burning of grasslands and prairies increases habitat favored by elk and increases the nutritional value of the forage.

There are probably more black bears in the region than when Euro–Americans first arrived in large numbers after the Gold Rush. This increase can be attributed to less competition with grizzly bears after their extirpation in the early 1920s and an increase of favorable habitat following extensive timber harvest in the region. Black bears are attracted to human foods and quickly learn to associate humans with food. The parks have an active bear management program that relies on educating park users about the importance of proper storage and disposal of food-related items and trash. The program also includes aversive conditioning of bears to humans and human food sources. Numerous human food sources such as garbage and gardens exist adjacent to the parks, making it difficult to keep the bears from learning to associate humans with food.

Mountain lions appear to be increasing in numbers in northern California and are being seen more frequently in the parks over the past few years. Some reported encounters with mountain lions have been unusual in that the lions did not flee immediately at the sight of humans. Such reports trigger close monitoring by RNSP staff to protect public safety. If necessary, trails may be temporarily closed to minimize human/lion contact.

RARE, THREATENED, AND ENDANGERED SPECIES

Threatened, endangered, candidate, rare, and sensitive plants and animals that are known to inhabit the parks or for which suitable habitat exists are presented in appendix H. All listed terrestrial species in the parks are birds.

Threatened and Endangered Plants

No federally or state listed, proposed, or candidate plant species have been encountered in the parks by RNSP botanists. No systematic surveys of the parks specifically for these or other sensitive plant species have been done; surveys for rare or sensitive plants are incidental to resource management or development projects. Western red lilly *(Lilium occidentale)* is a federally listed endangered plant species that occurs near the parks. There are no records of specimens from the parks. The closest known population is north of Crescent City. Potential habitat for western red lilly in the parks includes coastal scrub and coastal prairie vegetation types. Surveys specifically for lilies have not been conducted within the RNSP boundaries. Lilies have not been encountered during surveys in conjunction with projects at Enderts Beach; Deer Meadow; DeMartin, Lincoln, and Ossagon prairies; and a small prairie just north of the mouth of Redwood Creek.

Threatened and Endangered Terrestrial Wildlife

Two birds associated with old-growth forest, the northern spotted owl and the marbled murrelet, are the most prominent listed terrestrial species in the parks. Location and timing of RNSP operations, including maintenance and development of trails, roads, and facilities and activities that alter habitat, have been restricted to protect listed species, especially during breeding and nesting seasons. A conservation strategy has been developed for managing RNSP operations to protect these and other listed species from habitat loss and to minimize disturbance.

Northern Spotted Owl (*Strix occidentalis caurina*)

Spotted owls are typically found in old-growth forests in the parks. Second-growth forest older than 45 years and forest stands as small as 1 acre (or less with remnant old-growth trees) are considered suitable spotted owl habitat. Dense forest stands, with associated snags and large down log habitat components, provide the primary nesting and foraging habitat to ensure successful reproduction. The dusky-footed woodrat is the primary prey species for the spotted owl in northwestern California.

Suitable spotted owl habitat is defined as mature forest stands that have multilayered conditions, a canopy closure of at least 70% or greater, and obvious decadence (large, live coniferous trees with deformities such as cavities, broken tops, and dwarf-mistletoe infections.) The overstory should contain trees that are 21 inches or greater diameter at breast height (dbh) and should comprise at least 40% of the total canopy closure. In inland forests adjacent to the parks, some stands with less than 40% overstory canopy closure are also considered suitable owl habitat. These stands typically have a hardwood understory, which increases the total canopy closure to 60% or greater. Suitable habitat should contain numerous large snags, group cover characterized by large accumulations of logs or other woody debris, and a canopy open enough to allow owls to fly within and beneath it.

In Redwood National and State Parks, vegetation analysis indicates that there are 55,000 acres of habitat suitable for roosting, foraging, and nesting for spotted owls. This includes all old-growth and uncut forests and second-growth forests that were cut more than 40 years ago. Another 37,000 acres may be suitable foraging habitat.

There is no designated critical habitat for the northern spotted owl in the parks.

Thirty-nine northern spotted owl activity centers have been located in Redwood National and State Parks since 1993. An activity center may be occupied by a pair or a single owl. An average of 24 activity centers have been known to be occupied (annually). Between 6% and 40% of the known pairs of owls will successfully fledge at least one young bird annually, but only one territory has fledged young more than two times in the last five years.

All of the suitable habitat in the parks was systematically surveyed for spotted owls following established protocols approved by the U.S. Fish and Wildlife Service in a three-year project completed in 1995. All owl territories recorded in 1993 and 1994 surveys of selected areas were revisited during the 1995 surveys. Nesting status could not be verified in all known territories during the 1995 survey. Sixteen pairs were recorded in 1995. Three of these attempted nesting, and one pair successfully fledged two owlets. In 1993, five of 13 pairs attempted to nest; three pairs each fledged one young. In

1994, seven of 23 pairs attempted to nest, and seven pairs successfully fledged a total of 8 young.

Marbled Murrelet
(Brachyramphus marmoratus marmoratus)

Marbled murrelets range from Alaska south to central California. These robin-sized birds feed on fish in ocean waters within 1 mile of shore, returning to inland roosting and nesting sites in the early morning and evening. Known nest sites are in mixed stands of mature and old-growth coniferous forests within 35 to 50 miles of the ocean. Suitable nesting habitat consists of mature and old-growth forest with nesting platforms and adequate canopy cover surrounding the nest site. Most of the known population in California occurs in Redwood National and State Parks and other state parklands or on private timberlands close to the coast.

Murrelet nests are difficult to locate because most nests are high in the canopy, birds are camouflaged by their coloring, adults are often quiet in the vicinity of nests, and adults may only move once a day during low light conditions (Paton 1995 and USFWS 1996b). Instead, identification of occupied sites and suitable nesting habitat are the best indicators of potential nest sites. Indicators of occupied habitat include active nests; egg shell fragments; young found on the forest floor; marbled murrelets seen flying through the forest beneath the canopy, landing in trees, circling above the canopy, and calling from a stationary perch; or large numbers of murrelets heard calling from in and around a forest stand (Paton 1995; USFWS 1996b). Observed “occupied behavior” is used as a substitute for direct observations of murrelet nesting. Occupied behavior is a specific pattern of flight that is considered by the U.S. Fish and Wildlife Service to indicate the use of a stand of trees for nesting by marbled murrelets (USFWS 1996b).

The three state parks contain habitat for marbled murrelets that has been designated as critical habitat under section 4 of the Endangered Species Act. The primary constituent elements of critical habitat are defined as

> individual trees with potential nest platforms and forest lands of at least one half site-potential tree height regardless of contiguity within 0.8 kilometers (0.5 miles) of individual trees with potential nesting platforms and that are used or potentially used by marbled murrelets for nesting or roosting. (USFWS 1996b)

Habitat characteristics associated with murrelet nesting are large trees with lateral branches at least 6 inches in diameter, which provide nesting platforms, and a mature understory that extends into the canopy of the old growth, which provides protection for potential nest sites. Forest stands containing trees greater than 32 inches in diameter may be considered suitable nesting habitat. Trees must have large branches or deformities for nest platforms, with the occurrence of suitable platforms being more important than tree size alone (USFWS 1997). Douglas-fir, coastal redwood, western hemlock, and Sitka spruce are the trees most likely to provide suitable nesting structure (Hamer and Nelson 1995)

Nesting habitat includes the forest stand in which the nest trees are contained. Nest stands are defined as contiguous mature and old-growth forest with no separations greater than 100 meters (330 feet) wide. Although stands of old-growth trees larger than 500 acres are more likely to be occupied by murrelets, birds have been detected in smaller stands in the parks (Hamer and Nelson 1995; Carolyn Meyer, University of Wyoming, pers. comm., August 1997).

Analysis of the vegetation in the parks indicates that old-growth forest and other suitable nesting habitat for marbled murrelets totals about 43,000 acres. Second-growth forest without the habitat elements critical for nesting totals 45,000– 50,000 acres.

Marbled murrelet detections in the parks have been made in the Tall Trees area (24 observations), within the Lady Bird Johnson grove (14), Lost Man Creek area (26), and the old-growth forests throughout Prairie Creek Redwoods State Park (120) (Howard Sakai, RNSP supervisory ecologist, pers. comm. 2/24/97).

The probability of predation at nest sites increases with habitat modification (Divorky and Horton 1995). Potential predators include raccoons, great horned owls, ravens, crows, Steller's jays, and peregrine falcons, all of which are known to occur in the parks. Nesting failures of 23 nests have been documented from predation (61%), chicks falling from nests, and human disturbance (Nelson and Hamer 1995).

Humans in old-growth forests could create noise that may disturb nesting murrelets. If an adult leaves a nest, an unprotected chick is at risk of being preyed upon. Humans may also bring in food or litter that attracts corvid bird species (ravens, crows, and jays). Ravens and jays prey on murrelet nestlings and eggs (Nelson and Hamer 1995). These and other predators such as raccoons, owls, and gulls, are known to use human-made corridors such as roads for access into dense forests and to frequent areas that are heavily used by humans, such as campgrounds and picnic areas (Nelson and Hamer 1995). RNSP staff are gathering data to determine whether corvids are found in higher numbers along trails and other areas of human disturbance (Rick Wallen, RNSP fish and wildlife ecologist, pers. comm. 7/11/97).

Brown Pelican *(Pelecanus occidentalis)*

Pelicans are commonly seen flying over the Pacific shoreline. The brown pelican hunts fish that are swimming near the surface, but it will also hunt in the larger lagoons and estuaries. Although brown pelicans are not known to nest in the parks, analysis of potential habitat indicates that there are about 1,600 acres of suitable roosting and foraging habitat in the parks. The closest breeding colony is on Anacapa Island off the southern California coast.

Western Snowy Plover *(Charadrius alexandrinus nivosus)*

The sandy beaches and coastal dunes throughout the parks are potential nesting habitat for snowy plovers. A systematic survey of Gold Bluffs Beach from Fern Canyon to Carruthers Cove was conducted between March and August of 1995 by a Humboldt State University student. RNSP staff has conducted additional systematic breeding and winter season beach transect surveys at Freshwater Spit and Gold Bluffs Beach from Carruthers Cove south to Ossagon Rock. Systematic surveys to compare winter (December–February) and summer (May–June) use of beaches were initiated in December 1996. Surveys are planned for four years, after which the time the program will be reassessed to determine the survey cycle. Planned winter surveys for the sand spit at the mouth of the Klamath River were canceled after high water washed away the spit in January 1997. No nesting plovers have been found following completion of the summer 1997 surveys. However, the birds are known to nest at Stone and Big Lagoons, a few miles south of Freshwater Spit.

Plover populations in the region are thought to have declined because of increased human use of beaches (*Federal Register* 1993). Plovers foraging at Gold Bluffs have been killed by off-highway vehicle traffic (Gary Strachan, State Park Ranger, pers. comm. 1995). Moving Highway 101 onto Freshwater Spit in the late 1950s probably contributed to the decline of potential nesting populations in the parks (Rick Wallen, RNSP fish and wildlife ecologist, pers. comm. 8/19/97).

American Peregrine Falcon *(Falco peregrinum anatum)*

Peregrine falcons typically nest on ledges on cliffs and nearly vertical rocky outcrops. The steep coastal bluffs are potential nesting habitat for peregrine falcons. They feed primarily on birds and prefer foraging in riparian forest habitat and along coastal bluffs.

The parks’ wildlife observation database records about four sightings annually since the early 1980s. The observed behavior and regular sightings of falcons suggest that they are nesting in the region. At least one eyrie site is known in the parks. The number of peregrine nest sites in northern California has steadily increased during the last 10 years.

Bald Eagle *(Haliaeetus leucocephalus)*

Bald eagles are most commonly observed at the mouths of Redwood Creek and the Klamath River, at Freshwater Lagoon, and at coastal areas and prairies where dense forests do not obscure the view. Most observations are during the winter and are likely birds that are migrating through the area.

Bald eagles feed primarily on fish and water-fowl, but also forage on carrion. Bald eagles are most commonly observed at the mouths of Redwood Creek and the Klamath River, at Freshwater Lagoon, and at coastal areas and prairies. Most observations in the parks are during the winter and are likely northern birds that have migrated south to find food where rivers, streams, and lakes are not frozen or covered with snow. Although no bald eagle nesting activity has been documented in the parks, the potential of finding a breeding pair is high because an established summer territory is known. Nesting usually occurs near lakes, streams, and rivers in large old trees in open, uneven-aged mature or old-growth forests.

Bald eagles typically roost in snags and dead branches in groups of several individuals. There are no known roosting areas or territories in the parks.

Noise in Relation to Threatened and Endangered Wildlife

Noise has been identified as a source of disturbance and thus a potential threat to some listed threatened and endangered species, particularly to northern spotted owls and marbled murrelets during their respective breeding seasons (USFWS 1997; Carolyn Meyer, RNSP supervisory ecologist, internal memorandum, March 2, 1994).

Background noise in the interior of the parks is generally much lower than that expected or tolerated in developed areas in which the federal noise guidelines are generally applied. Very limited measurements of noise have been taken to estimate the noise generated by trail maintenance activities in old-growth habitat. Background noise measured by staff biologists and maintenance staff in the forest ranged from 45 to 60 dBAs. Chainsaws were measured at 100 dBA at 10 feet away; 82 dBA at 100 feet; and 44 dBA at 500 feet (Redwood National Park memorandum to U.S. Fish and Wildlife Service, 6/23/93). These were instantaneous measurements, rather than L_{10} or L_{eq} (see appendix J for definitions).

Sources of noise in Redwood National and State Parks and the vicinity include local communities and their commercial and residential areas; legal use of firearms on adjacent private lands and illegal poaching; highway traffic, especially brakes on large trucks; aircraft; powerboats on Freshwater Lagoon and in the Klamath River estuary; heavy industry such as timber harvest operations on adjacent private lands; construction and maintenance activities in the parks and on adjacent private land; humans using roads, trails, campgrounds, and other facilities in and adjacent to the parks; humans off trails and roads; wildlife such as elk bugling and birds calling; wind, rain, and thunder; and the sounds of the ocean, rivers, and streams.

RNSP operations generate noise from personnel; vehicles; large and small generators; hand tools such as hammers and power saws; heavy equipment such as backhoes, tractors, mowers, and bulldozers; and smaller power equipment such as chain saws, wood chippers, cement mixers, generators, and weedeaters. Noise from RNSP operations is generally confined to the daylight hours, between 7 A.M. and 6 P.M.

Concentrated human activity generates noise primarily during daylight hours in park areas including the two outdoor schools, campgrounds, picnic areas, trailheads, visitor centers, housing, and maintenance areas. Noise from the campgrounds and the outdoor schools may be produced between 6 A.M. and 10 P.M.

Qualitative determinations of noise levels can be made for several locations and noise sources throughout the parks. Baseline, or ambient, levels of noise are highest in intensity and most frequent or of long duration in the Highway 101, 199, 197, Howland Hill, and Bald Hills Road corridors; near Orick, Klamath, Requa, Crescent City, and Hiouchi; at industrial sites and developed areas in the parks; and near the ocean. High intensity but infrequent noises include storms, firearms, aircraft, and construction and maintenance activities that use heavy equipment, chainsaws, or other noise-producing tools. Storms are infrequent on an annual basis but may produce intense noise for short periods and be several days in duration.

Noises produced by visitors using trails or roads are low to moderate in intensity and of short duration for any given point, depending on how fast someone walks or drives. Spoken conversation is assumed to produce noise in the 45 to 60 dBA range. Noises from backcountry campsites are infrequent, low to moderate in intensity, and generally less than 24 hours in duration.

Threatened and Endangered Fish

One fish species, the tidewater goby, which inhabited the coastal estuaries in the parks as recently as 1980, is listed as endangered. Four species of fish in the salmon family (referred to as salmonids) that inhabit the parks are listed, proposed for listing, or candidate species for listing under the federal Endangered Species Act. The southern Oregon/northern California coastal coho salmon is federally listed as threatened. The southern Oregon/coastal California populations of chinook salmon are proposed for federal listing as threatened. Critical habitat for coho and chinook salmon that inhabit the parks has also been proposed for RNSP streams. The coastal cutthroat trout and the Northern California and Klamath Mountains Province populations of steelhead trout are federal candidate species for listing as threatened.

Tidewater Goby *(Eucyclogobius newberryi)*

This fish occurs in coastal estuaries that are tidally influenced. It was known from Freshwater Lagoon and the Redwood Creek estuary. Specimens were obtained from the Redwood Creek estuary in 1980. Since that time, no gobies have been encountered in surveys of the estuary done in conjunction with monitoring for juvenile salmonids. No systematic tidewater goby survey has ever been conducted in the parks.

Salmonid Fishes

Four species of salmonids that inhabit the parks are important as sport or commercial fisheries: chinook and coho salmon and steelhead and coastal cutthroat trout.

These species are anadromous. Anadromous fish migrate as juveniles from freshwater to the ocean (after a few months to several years of freshwater rearing), grow to adulthood in the ocean in two to five years, and return to spawn in freshwater. The strong homing tendency of anadromous fish leads to the evolution of subpopulations of fish or “stocks” that are adapted to their native streams (Ricker 1972).

The salmon in the parks belong to the group known as Pacific salmon. Pacific salmon die after spawning. Unlike other Pacific salmon, steelhead may spawn more than once before they die. Pacific salmon are among the most important sport and commercial fishes in the world. The extremely high value of these fish as food and a yearly abundance as the fish move from the ocean into freshwater led to permanent human settlements in places where the food literally came to the people. The food value led to the development of complex commercial industries. The exploitation of the fish and the competition among Pacific nations caused the establishment of international, national, and regional commissions to regulate the fishery (Scott and Crossman 1973).

Different stocks of fish of the same species may migrate into freshwater at different seasons and in different stages of maturity. These stocks are commonly referred to by the season when they migrate into freshwater, e.g., summer and winter steelhead or spring-run and fall-run chinook. Fish stocks throughout the Pacific Northwest region are threatened by the cumulative impacts of livestock use, road construction, timber harvest, stream channelization, water diversions, hydroelectric development, overfishing, and the influence of hatchery fish on both disease resistance and genetic fitness of native stocks (NMFS 1997a and 1997b).

The numbers of anadromous fish are governed by conditions in both freshwater and marine environments. Three factors have the greatest potential to affect the quality and quantity of freshwater habitat: water temperature, fine sediment, and habitat complexity or cover. Good freshwater habitat for anadromous fish contains complex habitat with both wood and rock, spawning gravels with low levels of fine sediment, water temperatures rarely more than 60°F., shade cover, and a well-developed riparian zone (USFS 1995).

The major fish-producing rivers and streams in and upstream of the parks are the Smith River, its tributary Mill Creek (particularly the West Branch), the Klamath River, Redwood Creek, and its tributary Prairie Creek.

Only the mouth of the Klamath River is within the parks, and there is no suitable spawning habitat in this portion of the Klamath River. Fisheries in the Klamath are managed by the Yurok Tribe, the California Department of Fish and Game, the National Marine Fisheries Service, the U.S. Fish and Wildlife Service, and the Pacific Fisheries Management Council. Chinook salmon and steelhead are major sport fisheries on the Klamath. Fall-run chinook at the mouth of the Klamath and steelhead in the winter are an important source of tourism income for the town of Klamath. Fifty percent of the Klamath anadromous fishery is allocated for Yurok Tribal member subsistence and commercial use.

During winter and spring, steelhead and chinook are major sport fisheries in the Smith River. The large size of Smith River salmon and steelhead gives the river national prominence among sportfishing enthusiasts. The California state record steelhead (more than 27 pounds) was caught in the Smith River.

Coho are widely distributed in the Smith River basin, with the most significant populations in Jedediah Smith Redwoods State Park. Only occasional spring-run chinook and summer steelhead are observed in the Smith River. Anadromous coastal cutthroat are widely distributed through the Smith River drainage, but they are not abundant (USFS 1995).

Mill Creek (in Del Norte Coast Redwoods State Park and Jedediah Smith Redwoods State Park) and Prairie Creek (in Prairie Creek Redwoods State Park) are important spawning grounds for chinook and coho salmon and steelhead and coastal cutthroat trout. Sportfishing in Prairie Creek occurs in summer when the trout season is open. At that time of year, the most likely fish caught will be cutthroat and juvenile steelhead (David Anderson, RNSP fishery biologist, pers. comm. 1996–97).

Redwood Creek is used by chinook and coho salmon, steelhead, and coastal cutthroat trout. The lower third of the Redwood Creek watershed is within the national park, as is the mouth of Redwood Creek and a portion of its estuary. The estuary is a holding area for juvenile fish before they migrate from freshwater to the ocean. Young chinook salmon and some steelhead trout juveniles produced in the upstream reaches of the creek and the tributaries migrate downstream to the estuary in summer. Low summer river flows cause a sandberm to build that blocks the flow of the creek into the ocean. Chinook, steelhead, and sea-run cutthroat trout live in the estuary embayment where they feed on invertebrates and grow to a size that will enhance their chance for survival during the ocean stages of their life cycle. Juvenile fish migrate out to the ocean in the late fall or winter when the winter rains make the creek rise and break through the sandberm. Artificial breaching of the sandberm in the summer causes the juvenile fish to enter the ocean at a smaller size, which may decrease the chances of survival for these fish.

Chinook (Oncoryhnchus tshawytscha). Chinook salmon, the largest salmonid occuring in the parks' rivers and streams, spawn primarily in the larger streams, including the Smith River, the Klamath River, Redwood Creek, and the main stems of Mill Creek, Lost Man Creek, and Prairie Creek.

Chinook typically return from the ocean to rivers, larger streams, and larger tributaries to spawn between November and early January. Chinook return to the Klamath in August and September. In spring, chinook salmon fry (early life stage that develops from the egg) migrate downstream to rear in the Redwood Creek estuary before entering the ocean in the fall. Chinook salmon usually return to freshwater after three to four years in the ocean, although two-year-old male spawners are commonly observed.

Winter-run chinook constitute the main chinook runs in RNSP streams. These fish arrive around November and have spawned and died by January. Adult spring-run chinook were observed in only one season since 1981 when the NPS staff began surveys. Spring-run chinook do not typically use Redwood Creek.

On March 9, 1998, the National Marine Fisheries Service proposed to designate critical habitat for the southern Oregon/California coastal populations of chinook salmon. Critical habitat within the parks consist of the water, substrate, and adjacent riparian zone of estuarine and riverine reaches of RNSP streams accessible to chinook. Accessible reaches are those within the historical range of the populations that can still be occupied by any life stage of chinook salmon. There are no sections of streams within the parks that are inaccessible because of specific dams identified in the NMFS proposal or because of longstanding, naturally impassible barriers such as natural waterfalls in existence for at least several hundred years. Adjacent riparian zones are defined as those areas within a horizontal distance of 300 feet (600 feet when both sides of the channel are included) from the normal line of high water of a stream channel or adjacent off-channel habitats.

Coho Salmon (*Oncorhynchus kisutch*). Coho salmon, smaller than the chinook, spawn in the Smith River, the main stem of Mill Creek, Redwood Creek, Prairie Creek, and some of the smaller tributaries of these creeks.

Coho salmon have a simple (relative to other anadromous Pacific salmon) three-year life cycle. Adult coho return to freshwater between November and early February to spawn.

Coho use a variety of spawning sites but characteristically enter small coastal creeks or tributary headwaters of larger rivers to spawn. The tiny fry occupy shallow streams next to pools but move into deeper water as they grow. Coho salmon juveniles remain in the streams for one year before migrating to the ocean, typically between March and May. Most coho salmon return to freshwater after two years in the ocean. Optimal rearing habitat for juveniles is pools deeper than 3.5 feet (1 m) that contain logs, large tree roots, or boulders in heavily shaded sections of the streams.

On November 25, 1997 (NMFS, 1997), the National Marine Fisheries Service proposed to designate critical habitat for the southern Oregon/northern California coastal populations of coho salmon. Proposed critical habitat includes all waterways, substrate, and adjacent riparian zones of estuarine and riverine sections accessible to coho salmon. Accessible sections are those within the historical range of the fish populations that can still be occupied by any life stage of coho salmon. There are no sections of streams within the parks that are inaccessible because of specific dams identified in the NMFS proposal or because of longstanding, naturally impassible barriers such as natural waterfalls in existence for at least several hundred years. Adjacent riparian zones are defined as those areas within a horizontal distance of 300 feet (600 feet when both sides of the channel are included) from the normal line of high water of a stream channel or adjacent off-channel habitats.

Steelhead Trout (*Oncoryhnchus mykiss*). Steelhead trout are the last of the salmonid species to return to freshwater in the annual cycle, generally between January and April. Steelhead trout juveniles rear in the streams for one to four years before their migration to the ocean. They then reside in marine waters for typically two or three years before returning to freshwater to spawn. Unlike other Pacific salmon, steelhead are capable of spawning more than once before they die. However, it is rare for steelhead to spawn more than twice before dying; most that do so are females, provided there are no barriers to migration and adequate amounts of water are left in the stream during the dry summer months.

Steelhead can be divided into two reproductive types, based on their state of sexual maturity at the time of river entry and the duration of their spawning migration. These two types are termed "stream maturing" and “ocean maturing.” Stream-maturing steelhead enter freshwater in a sexually immature condition and require several months to mature, after which they spawn.

Stream-maturing steelhead are also known as summer steelhead. Ocean maturing (or winter) steelhead enter freshwater in a mature state and spawn shortly after river entry. Summer steelhead return to a river or stream from spring to early fall and remain in deep pools until spawning occurs. The long freshwater holding time renders the adult steelhead especially vulnerable to predation and habitat changes.

On March 19, 1998, NMFS published its determination that the Klamath Mountains Province and Northern California populations of steelhead do not warrant listing as threatened species at this time. NMFS determined that these populations do warrant classification as candidate species. The status of these fish will be reevaluated within four years to determine whether they should be listed. The candidate species include steelhead populations occurring in coastal streams between Cape Blanco, Oregon, and the Klamath River basin in Oregon and California, inclusive (Klamath Mountains Province), and populations occupying coastal river basins from Redwood Creek in Humboldt County south to the Gualala River in Mendocino County, California, inclusive.

Both large rivers and small streams may have suitable habitat for steelhead. One type of coastal stream is the small, generally intermittent headwater streams at the northern end of Prairie Creek Redwoods State Park that are tributaries to the Klamath. These are unsuitable for steelhead because of inadequate flows and the lack of suitable spawning habitat. Another type of coastal stream are small streams that enter the ocean directly, rather than as a tributary of a larger river or creek. These streams have a limited potential for salmonid production because of small size, inadequate flows, and the lack of suitable spawning habitat. However, the lowermost reaches of Cushing Creek and Nickel Creek to the north have a small amount of suitable spawning habitat for steelhead and may be used in wet years.

Redwood Creek has both summer and winter runs of steelhead. The summer run has declined since surveys began in 1981. The most summer steelhead seen during NPS summer surveys of portions of the main stem of Redwood Creek is 44 fish. Few fish were seen in the mid-1990s. No other streams within the parks in the Redwood Creek basin have been surveyed because these streams do not have large enough pools to support adult fish during the warm summer months.

Coastal Cutthroat Trout (*Oncoryhnchus clarki*). Coastal cutthroat trout are native to northwestern California, occurring northward from the Eel River drainage, about 50 miles south of the Redwood Creek. Cutthroat inhabit most coastal streams, especially in the Prairie Creek drainage, Espa Lagoon, the streams that drain into the ocean along Gold Bluffs Beach, and Mill Creek.

Adult anadromous cutthroat return to freshwater in late autumn and early winter and spawn in small streams between February and May. Cutthroat trout are often found in the summer in the Redwood Creek estuary. RNSP fisheries staff suspect that a few resident, nonmigratory populations of cutthroat trout inhabit the tributaries of Redwood Creek.

Coastal cutthroat occur in the same waters as rainbow trout, but they generally spend more time in smaller tributaries and headwater reaches. Cutthroat compete with rainbow trout where the two species live together. Rainbow trout are a resident form of steelhead trout.

The lowermost reaches of Cushing Creek and Nickel Creek, which drain directly into the ocean in the northern part of the national park, have resident and perhaps anadromous populations of coastal cutthroat trout.

Other Threatened and Endangered Wildlife Species

The Oregon silverspot butterfly *(Speyeria erene hippolyta)*, a federally listed threatened species that occupies coastal scrub, is not known to occur in Redwood National and State Parks. The closest known population occurs near Lakes Earl and Talawa about 3 miles west of Jedediah Smith Redwoods State Park.

Four species of sea turtles known from the north Pacific Ocean are federally listed as threatened or endangered (green sea turtle, *Chelonia* *mydas*; loggerhead sea turtle, *Caretta caretta*; olive ridley sea turtle, *Lepidochelys olivacea*; and leatherback sea turtle, *Dermochelys coriacea*). Sea turtles typically are more common in warmer oceans. The coastal area of the parks is too cold for breeding for these species. No breeding beaches have been documented in California. These turtles do occur occasionally in offshore waters, as strandings have been noted by marine mammal rescue groups, but any animals found on the beaches are either sick or injured. Consequently, turtles are considered transients, and no important habitat features exist in the parks that are crucial to the turtles.

Redwood National and State Parks are within the range of the Aleutian Canada goose *(Branta canadensis)*, federally listed as threatened. These birds forage on flat areas such as low-elevation riverbottoms and agricultural pastures. Aleutian Canada geese are known to forage at the Smith River riverbottoms a few miles northwest of the Jedediah Smith Redwoods State Park and at Patrick's Point State Park about 15 miles south of the mouth of Redwood Creek. Undoubtedly they use the coastline as a flyway. No observations have been recorded for RNSP lands.

The northern (Steller) sea lion *(Eumetopias jubatus)* is federally listed as threatened. Steller sea lions do not habitually enter bays, estuaries, or river mouths. They inhabit the outer coast, resting on flat offshore rocks and rocky islands. These sea lions have been observed occasionally at the mouth of the Klamath River as they migrate along coastal waters. Northern sea lions use large, flat surface rocks for breeding. The offshore rocks within the RNSP coastline are too steep to be suitable for breeding. The closest breeding colony is at Cape Mendocino, about 100 miles south of the parks.